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ACTIVITY COSTS OF CATTLE IN THE WEST AFRICAN SAVANNA

by

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ABSTRACT

The thesis is presented in three parts. The first part reviews factors and constraints to cattle production in the savanna regions of West Africa. It was concluded that kraaling of cattle during the dry season could seriously curtail the time available for grazing and may result in low nutrient intake and liveweight losses. High ambient temperature and high levels of solar radiation could increase the heat load on grazing cattle and indirectly reduce feed intake. Furthermore, the existence of mild disease levels within cattle herds could reduce animal productivity even among the trypanotolerant cattle breeds.

The second part of the thesis reports a study undertaken to estimate the energy cost of eating activity by cattle. Five 1.5 year old steers were offered five chemically and physically different feeds. Energy cost of ingestion was calculated from the increased rate of oxygen uptake. The feeds were pelleted concentrate, pelleted alfalfa, alfalfa hay, chopped grass hay and and chopped fresh turnips. The pellets and hays contained approximately 90% dry matter while the turnips contained only 14% dry matter. The rates of ingestion differed markedly among feeds during the limited (15 to 50 min) twice daily eating periods. On dry matter basis the rates of ingestion were 130 to 138, 38, and 30 g/min for the pellets, hays and turnips, respectively.

The energy costs of eating per minute spent eating were similar for all rations (27.6 to 35.6 joules/min/kg body weight). However, because of different rates of ingestion, the energy costs per kg of dry matter ingested per kg body weight were, for the pelleted feeds 222 to 238 joules, for the hays 778 to 1029 joules and for the turnips 1427 joules.

In part three of the thesis, selected districts in the Ghanaian savanna, respresenting the Sudan, Guinea and Derived savanna zones and the cattle management systems therein were analysed as case studies. Energy budgets were calculated for the typical cattle in the three regions.

In the Bawku district (Sudan savanna zone) where kraaling and free-ranging is practised during the dry season, cattle were estimated to gain liveweight at 0.7 kg/day during the wet season and, during the dry season, lose 0.3 to 0.6 kg/day under the kraaling system and 0.1 to 0.5 kg/day under free-ranging conditions. Overall annual liveweight gains were estimated as 41 kg and 79 kg under the kraaling and free-ranging conditions, respectively.

Estimated liveweight gains for cattle in the Tamale district (Guinea savanna zone) were 0.5 kg/day during the wet season and liveweight losses were estimated to be between 0.2 and 0.6 kg/day during the dry season. Annually, kraaled cattle were estimated to increase in liveweight by only 28 kg.

Similarly, cattle in the Techiman district (Derived savanna zone) were estimated to gain 0.4 to 0.5 kg/day

during the wet season and lose 0.1 to 0.2 kg/day during the dry season. Total annual liveweight gain by kraaled cattle was estimated to be 73 kg.

Reduced metabolizable energy intake and elevated energy expenditure involved in daily activities were determined to be major causes of the liveweight losses during the dry season.

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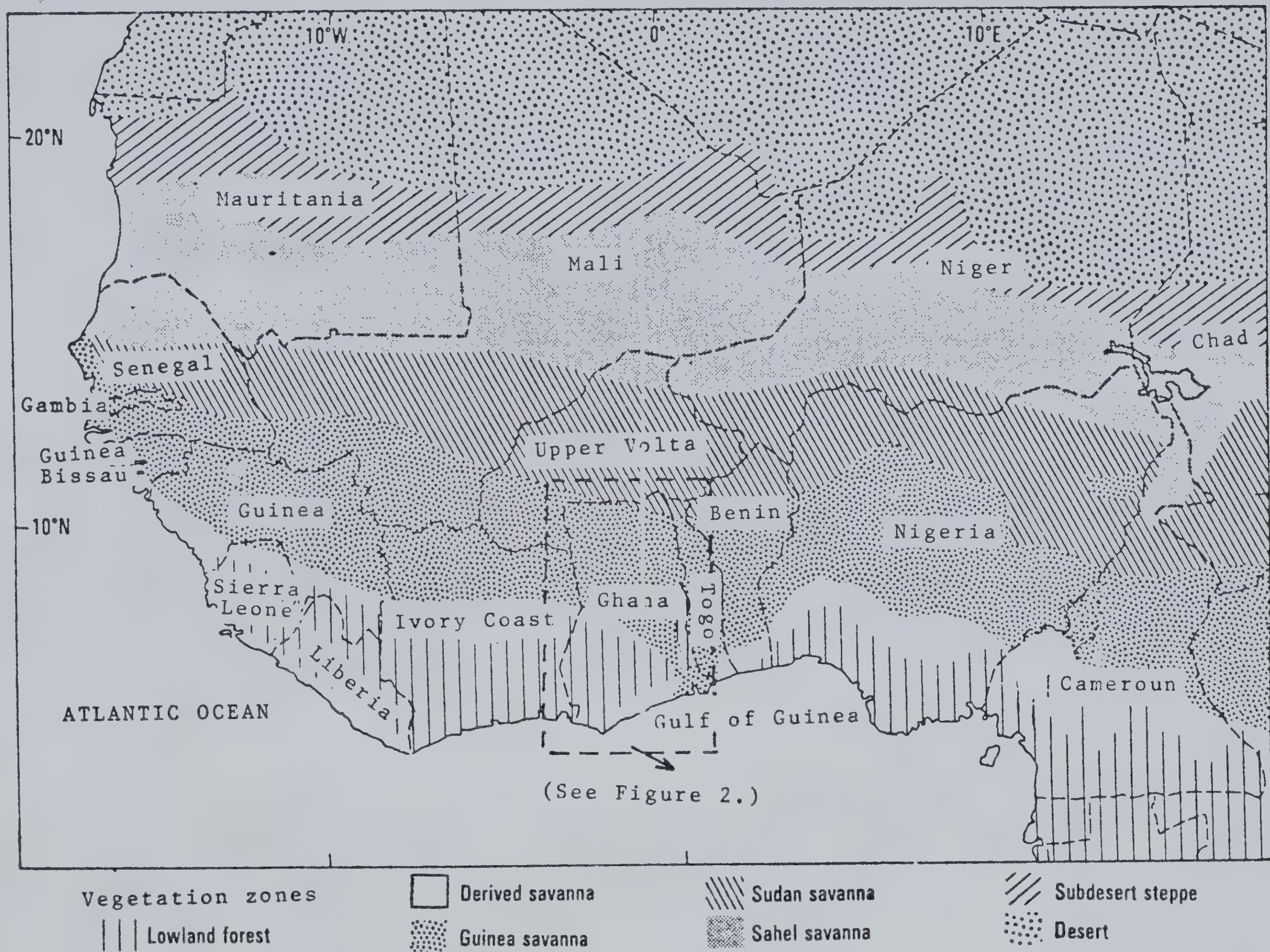
INTRODUCTION

Grazing cattle spend a considerable amount of time engaged in various physical activities, particularly those concerned with the prehension and ingestion of feed. The energy utilized for activities such as standing, walking, grazing and ruminating could account for a large proportion of the animal's daily energy requirement. Over 90% of the 35 million head of cattle in West Africa are raised in the grazing lands of the savanna vegetation zones which are characterized by distinct wet and dry seasons. These savanna zones are shown in Figure 1. The Derived savanna zone which occurs at the northern fringe of the coastal lowland forest has 4 to 5 months of dry season (Crowder and Chheda, 1977) and the number of dry months of the dry season increases progressively northwards from Derived savanna zone through the Guinea, Sudan and Sahel savanna zones and finally to the desert area of north Africa.

In the savanna regions the management of livestock is largely traditional in technique. Following the rainy season when feed is abundant animals gain liveweight but much of this gain is lost during the subsequent dry season when the cattle are herded over long distances across unimproved grazing grounds in search of feed and water. The net annual liveweight gain by young stock is therefore only between 45 and 70 kg (Mittendorf, 1963, as cited by Oyenuga, 1966). These liveweight gains are small compared to the performance

Figure 1. Vegetation zones of West Africa (Redrawn from Keay, 1959)



of cattle on improved pastures in the tropics (Leeuw, 1971, as cited by Crowder and Chheda, 1977; Smith, 1970).

In the opinion of Oyenuga (1975) the bulk of the meat produced in West Africa will, at least in the foreseeable future, continue to come from the traditional production systems. The reasons for this situation are largely socio-economic and political. At present, traditional farmers find it economically sound to keep their capital in the form of live animals and also because cattle play a significant role in their customary practices. An unfortunate consequence of this system is the overstocking of rangelands particularly in the virtually tsetse-free zones of the Sahel and Sudan (Ormerod, 1976). However, present considerations make it all the more expedient for animal scientists and for others concerned with increasing the productivity of cattle in West Africa to examine more closely the factors operating within the traditional systems of beef production. This thesis examines the environmental and other stresses on animals and the effects on the daily activities and the energy status of cattle inhabiting the savanna regions of Ghana. It is hoped that with identification and a greater understanding of the extent of activity and the energy costs to cattle in these regions, it will be possible to determine more precisely the nutritional requirements of the cattle. Such knowledge may also help in the evaluation of management practices for improved cattle production.

1. REVIEW OF LITERATURE

1.0.0.1 Introduction

Animal responses to external environmental conditions such as climate, nutrition, disease and parasites have been reviewed by many researchers including Bianca (1965), McDonald (1968), Thompson (1973) and Murray et al., (1979). Although studies have been conducted in tropical and subtropical environments, there is a paucity of information specifically related to the cattle grazing systems used by the peasant herdsmen of the West African savanna. Hence, in this review, the preponderance of information has been obtained from places other than West Africa but has been interpreted with respect to conditions prevalent in West Africa.

1.0.0.2 Climate

Climate affects the animal in several ways. Firstly, climate has direct effects on the animal through ambient temperature, solar radiation, relative humidity and wind. Secondly, climate indirectly influences the growth of forages and the availability of feed for the grazing animal. And thirdly, climate indirectly plays a significant role in the seasonal incidence of disease vectors. In West Africa the savanna areas are characterized by a marked wet and dry season. The six or more months of the dry season are hot and of low humidity (Benneh, 1971; Oyenuga, 1966; Ussher, 1969).

While the direct effects of climate on cattle *per se* will be reviewed in this section, nutritional aspects and disease vectors will be considered briefly in the subsequent sections.

Climatic chamber studies involving exposure of cattle to hot environments have in general, shown that rectal temperature rises in relation to the duration of exposure and that an increased respiration rate usually precedes the rise in rectal temperature (Worstell and Brody, 1953; Bianca, 1965). The naturally occurring outdoor conditions are not static and the relevance to the natural environment of responses of cattle to heat stress in temperature-controlled room studies have been questioned (Robertshaw and Finch, 1976). For example, thermoregulatory responses under outdoor conditions tended to be related more to skin temperature than to deep body temperature obtainable in climatic chamber experiments (Finch, 1973, as reported by Robertshaw and Finch, 1976).

Cattle under heat stress may lose excess heat through evaporative cooling, convection or conduction. High relative humidity tends to suppress while mild wind enhances both convective and evaporative heat loss. Seath and Miller (1948) found that cows which had been stressed for two hours in direct sunlight cooled more rapidly with a combination of shade and a gentle breeze produced by a fan than with shade alone. Natural cross-ventilation proved superior to no cross-ventilation in a free-stall shelter and resulted in

significantly lower rectal temperatures and respiration rates, and higher milk production (Fuquay et al., 1976).

Yassen (1977) obtained significant correlations between ambient temperature and respiration rates in Boran and N'Dama breeds of cattle in Nigeria. The Boran breed , compared to the N'Dama breed, was more tolerant of the high afternoon temperatures as concluded from the relatively smaller increase in respiration rates measured daily at 14h00m and 16h00m. Where cattle are continually exposed to the sun in tropical savannas, the most powerful environmental heat stress has been reported to be associated with solar radiation (Robertshaw and Finch, 1976) and the activity of cattle in such regions and, specifically, their daily feeding pattern could be related to the effectiveness of the animal's coat in dealing with conditions of high radiant heat load (Lewis, 1977). The grazing animal is exposed to both direct solar radiation and long-wave radiation from the ground and other surfaces. In studies with Zebu cattle (Boran breed) in Kenya, Finch (1976) estimated that long-wave radiation accounted for 61% and short-wave radiation 39% of the estimated environmental radiation absorbed by the cattle coats. In the same studies she found that cattle coats absorbed two-thirds of the incident short-wave radiation resulting in a net radiative heat flow inwards to the animal body. This radiant heat represented 71% of the heat load while metabolic heat production was 29% of the heat load. Daily fluctuations in

heat storage in Finch's study represented 1% of the energy exchanges per day. Lighter coloured coats have been reported to reflect more short-wave radiation than dark coats while long-wave radiation is almost totally absorbed and is apparently independent of coat colour (Hammel, 1956). The magnitude of the heat load on cattle arising from radiations could be significant especially for the cattle foraging the savannas of West Africa during the dry season when grazing land is relatively scarce of vegetation and the skies are usually cloudless.

Animals under heat stress tend to reduce their voluntary intake of feed (Baile & Forbes, 1974) which may be a beneficial response to lower their metabolic heat production and increase comfort but a reduced feed intake reduces potential growth and productivity. Apart from the reduction in feed intake which occurs under conditions of heat stress there is an increase in water requirement and evaporative heat loss (Robertshaw & Finch, 1976).

The effect of high ambient temperature on reproduction in farm animals has been extensively reviewed (Bianca, 1965; Hafez, 1965; Thompson, 1973). Thus a few points only will be highlighted. If environmental temperature is excessively hot, direct heating of the scrotum adversely affects spermatogenesis which results in a depressed sperm concentration and mobility, and male fertility is reduced (Thompson, 1973; Hafez, 1965). Cows and heifers in hot climates exhibit frequent anestrus (Bond & McDowell, 1972)

and Poston, Ulberg & Legates (1962) found it difficult to detect estrus in cows during periods of hot weather. The review by Bianca (1965) contains information indicating that Holstein cows during the high temperatures of summer have a low rate of fertilization and a high rate of embryonic mortality. In most of the studies there also is evidence that the *Bos indicus* breeds are more heat-tolerant than the *Bos taurus* breeds but this climatic adaptation does not necessarily confer better productive capabilities on *Bos indicus* breeds.

1.0.0.3 Nutrition

One of the indirect consequences of climatic environment is its effect on the quality and quantity of herbage available to livestock at different times of the year. During the dry season forage is scarce and poor in quality. On the other hand, in the wet season the dry matter content of forage may be so low that cattle can consume insufficient amounts of nutrients to meet their energy and protein needs (Oyenuga, 1966). Although most grasses in the West African savanna region have relatively high nutritive value during early growth, this quality is rapidly lost with plant maturity. For instance an examination of twenty-five indigenous grass species in Ghana by Sen and Mabey (1966) indicated that crude protein content could be as high as 19.0% of dry matter in the wet season and only 2.5% during the dry season. This trend is similar to that observed in

other countries of the West African savanna. Gohl (1975) has compiled an extensive list of the nutritional qualities of tropical forages in relation to stage of maturity.

In some regions of the savanna the foraging lands are overstocked. Comparison of data on the grazing lands of north-eastern Nigeria revealed that in the tsetse-free zone there are some 2 million head of cattle while the zone's potential has been estimated to be only 1.2 million head (Leeuw, 1977). Thus through overgrazing the stress of low feed availability may be more pronounced during the dry period when herbage quality and quantity are very low.

At the Agricultural experimental station, Legon, cattle lost about 11% of their liveweight during the dry season (Rose-Innes, 1960). The low average annual liveweight gain of only 0.2 kg/head/day has been attributed to the effects of the dry season on feed availability and quality. (Montsma, 1963). Smith (1962) reported that *Bos indicus* steers on mature *Hyparrhenia* pasture ate a dry matter equivalent of 1.2% of their body weight when the herbage contained 50% of digestible organic matter (DOM) but as the dry season progressed, intake of herbage fell to 0.8% of body weight when DOM dropped to 38%. Marshall and Bredon (1967) found that voluntary intake of mature *Themeda triandra* by Zebu steers was equivalent to 0.5 to 0.8 of their maintenance requirements, while Elliott (1967) measured intakes of 0.7 of maintenance requirements by Africander and Mashona heifers given mature Rhodes grass.

There is evidence that cattle exhibit a remarkable ability to recover following a period of restricted nutrition (Yeates, 1964; Butterfield, 1966). This capacity is limited, however, under grazing situations with declining forage quality and/or availability (Joubert, 1954).

The physiological consequences of low intake of energy and of protein and other nutrients are profound. Growth is adversely affected by low energy and nutrient intake and the sensitivity of cattle to nutrient restriction is greatest in the neonatal period (Dickinson, 1960; Everitt, 1968). Moderate restriction of the calf from birth to 3 to 4 months of age resulted in a proportional extension of the growth period (Wardrop 1965, Everitt, 1972; Morgan, 1972). In the West African regions cattle indigenous to the area are bred for the first time when they are 3 to 3.5 years of age and cattle may take up to 6 to 8 years to reach a mature weight of 250 to 450 kg (Oyenuga, 1967). Poor nutrition of pregnant cows may also result in light birth weight of calves and, in lactating cows, a significant reduction in milk production (Jeffrey & Berg, 1971). Furthermore, under-nutrition in the lactating cow frequently results in a failure to conceive during the subsequent breeding season (Lamond, 1970).

1.0.0.4 Management of Cattle

In the savanna areas of West Africa, management of cattle is variable and many systems prevail. In the

northern-most parts of the region there is nomadic grazing and various aspects of mixed and settled agriculture. Night enclosure of cattle and daylight grazing is common (Oyenuga, 1966; Ormerod, 1976). The practice of night-enclosure or kraaling of cattle severely restricts the daily time available for grazing and has been suggested to be, in part, responsible for the limited weight gains by cattle (Smith, 1965). Smith (1965) also calculated that approximately 31% of the native cattle in Zambia had insufficient time to graze during the rainy season while in the dry season the number was 47%. This situation arose from kraaling animals too early in the evenings and taking them out to pasture too late in the mornings. Furthermore, since the time of departure to graze and the time the cattle are returned to the kraal are the responsibility of the herdsmen, any delay in releasing cattle to pasture in the morning forces the animals to graze at periods of the day when solar radiation and environmental temperatures are highest. Feed intake is likely affected by the heat load on the animal (Baile & Forbes, 1974). There are other reports which indicate that cattle, particularly during the dry season, are driven daily over long distances in search of feed and water (F.A.O., 1968; Lytle & Messing, 1976).

1.0.0.5 Diseases and Parasites

Both clinical and sub-clinical disease in cattle reduce their performance (Sewell,1976). In West Africa efforts by

individual governments and world organizations like the United Nations have led to the control and in some areas the eradication of the most serious cattle diseases such as rinderpest, contagious bovine pleuropneumonia and anthrax. However, outbreaks of different diseases periodically occur in localized areas (F.A.O., 1969; F.A.O., 1977). The role of management in the control of helminth diseases in beef cattle has been reviewed by Sewell (1976). Vercoe and Springell (1969) found that when helminths were present Hereford-Shorthorn cross steers had lower digestibilities of dry matter and nitrogen, lower nitrogen balances, and higher dialysable fecal nitrogen than did Brahman steers. However, when helminths were eliminated from the cattle, plasma gastrointestinal leakage, as measured by dialyzable fecal nitrogen, was reduced and total plasma protein was increased. The changes were most marked in the British steers. An important observation by these authors was that, at levels of infestation common in beef cattle under field conditions, no anemia or hypoproteinaemia may occur but losses of plasma nitrogen into the gastrointestinal tract may still be 2 to 3 times that in uninfested animals. Feed intake is reduced during many metabolic diseases and this decrease in feed intake is observed in most gastrointestinal disorders of either infectious or parasitic origin as well as many systemic diseases (Baile and Forbes, 1974).

In West Africa a major constraint to the development of large areas of potentially valuable agricultural land is the

presence of tsetse flies (*Glossina* spp.) and the trypanosomiasis diseases they transmit (Bourn, 1978). Tsetse flies occur over some 10 million square kilometers of the African continent (Bourn, 1978) and in West Africa there is a continuous spread of tsetse from the coast to the 14° N latitude (Squire, 1962). Only two of the seventeen West African countries are considered tsetse-free (Mauritania and Niger) and twelve are classified as being heavily infested, that is, more than 50% of the land area is infested (Bourn, 1978). Trypanosomes, transmitted by tsetse flies cause sleeping sickness of man and nagana of cattle (Ormerod, 1976). Cattle can be infected by any species of tsetse flies and unless animals are given prophylactic drugs their condition deteriorates in direct proportion to the degree of exposure to tsetse flies (Ormerod, 1976). Deterioration of body condition and the development of anemia are the common manifestations of the disease (Murray et al., 1979). There are, however, breed differences in tolerance or susceptibility to trypanosomiasis ('trypanotolerance') with the N'Dama breed believed to be the most tolerant (Murray et al., 1979). The trypanotolerance appears to be heritable . However, in areas where N'Dama cattle come under heavy challenge from the parasites, some of the trypanosome-infected animals die while most that survive often do so " *in a poor productive state with wasting, stunting, abortion, high calf mortality and with a persistent low-grade anemia being manifest* " (Murray et al.,

1979). Of the breed groups common in West Africa, the Zebu is most susceptible to the trypanosomiasis and the West African Shorthorn breed is intermediate between the White Fulani (Zebu type) and N'Dama in susceptibility.

An index calculated on the basis of reproductive performance, cow and calf viability, milk production, growth and cow body weight enabled Murray et al. (1979) to compare the effect of management systems and cattle breeds on trypanotolerance. They found that for trypanotolerance the effect of management system was a 38% lower productivity index per cow from the village herds compared with the ranch or station situation. Breed comparisons using the productivity index led the authors to conclude that the productivity of trypanotolerant cattle relative to other indigenous types may be higher than previously assumed, see above.

1.0.0.6 Daily Amounts of Animal Activities

In an effort to partition the daily energy expenditure of domestic animals, studies have been conducted on the isolated costs of such activities as rumination, feeding, standing, walking and grazing. Virtually all of these studies have been done with sheep in research laboratories, none of which are in West Africa. This review draws on the available information which could be reasonably applicable for extrapolation to cattle in West Africa.

Walking, standing and lying down studies conducted with

housed sheep and with sheep at pasture indicate that the grazing ruminant's maintenance requirements over and above those of penned animals are increased by 25 to 100% (Langlands et al., 1963; Lambourne and Reardon, 1963; Graham, 1964a; Young, 1966). Osuji (1973) as reported by Osuji (1974) suggested that the increased energy expenditure might be due to the increased overall costs associated with grazing, especially the costs of walking to and harvesting the forage. Furthermore, with both cattle and sheep it has been reported that grazing time increased linearly as pasture availability decreased (Lofgreen et al. 1957; Arnold, 1960).

Animals on poor pasture are reported to spend more time standing and walking about than conventionally housed animals (Graham, 1964a). In sheep and cattle the cost of standing over lying has variously been found to range from 0.25 to 1.59 kJ/kg/hr (see Osuji, 1974).

The costs of horizontal locomotion, achieved usually by force-walking an animal on a treadmill, have been determined by various workers. With sheep, Clapperton (1964) found that the energetic cost of walking was on average 2.5 joules/horizontal kg meter and this increased with speed of walking. The vertical component of the cost of horizontal locomotion was 26.6 joules/vertical kg meter. In hilly places therefore grazing livestock will expend more energy in searching for feed than animals on level ground. Furthermore, in seasons of drought or severe feed scarcity

animals are forced to expend extra energy in their search for feed under grazing systems which are basically nomadic such as practised in parts of West Africa by the nomadic Fulanis (Oyenuga, 1966; F.A.O., 1968). The energy cost of eating has been shown to be a direct function of the time spent eating by sheep (Osuji, 1973) as reported by Osuji (1974), while the cost of grazing activity has been suggested to be much greater than the cost of eating *per se* (Webster, 1972; Holmes et al., 1978).

Eating will be considered again in section two. Factors contributing to this increased expenditure may include the energetic cost of prehension, mastication, salivation and other physiological changes associated with the act (Webster, 1972; Osuji et al., 1975). Webster (1979) summarized the information on the energy cost of rumination and obtained an average value of 16.7 joules/min/kg liveweight for cattle.

The various energy cost values are summarized in Table 1.

1.0.0.7 Conclusions from the Review of Literature

In hot, radiative environments more than two-thirds of the daily heat load on grazing cattle could be due to solar radiation. Animals that are heat stressed reduce their voluntary feed intake, male animals have a depressed sperm concentration and mobility and female animals , possibly due to the difficulty in detecting estrus, have low rates of

Table 1. Published estimates for sheep and cattle and preferred values of estimates for cattle of the energy costs of activities

Activity	Energy cost of activity per kg liveweight: Preferred value†	Estimate	Source
Standing over lying		26.5 J/min	Armsby and Fries (1915)
		8.1 J/min	Forbes et al (1927)
	5.5 J/min	8.4 J/min	Hall and Brody (1933)
		4.2 J/min	Blaxter and Wainman (1962)
		7.0 J/min	McLean (1962)
		23.7 J/min	Graham (1964)
		9.4 J/min	Vercoe (1973)
Walking over standing			
horizontal component	2.1 J/min	2.3 J/m	Clapperton (1964)
		2.1 J/m	Ribeiro (1976) cited by Webster (1978)
vertical component	26.5 J/min	26.6 J/m	Clapperton (1964)
		26.5 J/m	Ribeiro (1976) cited by Webster (1978)
Eating		29.5 J/min	Dahn(1910) cited by Osuji(1974)
		19.5 J/min	Holmes et al (1976)
	45.0 J/min	27.8 J/min	Holmes et al (1976)
		39.7 J/min	Holmes et al (1978)
		45.0 J/min	Webster (1978)
Grazing	46.7 J/min	31.3 J/min	Holmes et al (1976)
		46.9 J/min	Holmes et al (1978)
		35.0 J/min	Webster (1978)
		16.7 J/min	Ustjanzew (1911)
Ruminating	16.7 J/min	16.7 J/min	Graham (1964)

† Summary of preferred values from A.J. Webster's (1978) review.

fertilization. In some cases embryonic mortality occurs in pregnant cows. In many parts of the tropics, particularly in those areas where the dry season is long, there are wide seasonal variations in the quality and quantity of feed. Grazing animals may consume only up to 70% of their daily energy requirements for maintenance. While poor nutrition of lactating cows leads to significant reductions in milk production and a possible failure to conceive during the subsequent breeding season, any feed restriction at any age results in reduced rate of growth.

The practice, among traditional herdsmen, of kraaling cattle has been suggested to restrict the daily time available for grazing. Disease and parasitic infestation cause morbidity in cattle. In particular, the prevalence of tsetse flies and trypanosomiasis in many parts of the West African savanna zones is of much concern. The Zebu breeds such as the White Fulani are most susceptible to trypanosomiasis. Under conditions of poor nutrition and heavy challenge from trypanosome parasites even the normally trypanotolerant N'Dama cattle become morbid. The extent of physical activities by cattle could affect their energy utilization and increase their maintenance energy requirements.

In the following section the cost of feeding activity in cattle is considered. The study was conducted at The University of Alberta Farm and has been prepared as a scientific paper with joint authors. The section following

the paper (chapter 2) contains an analysis of the cattle management systems in selected districts of Ghana.

2. ENERGY COST TO CATTLE OF FEEDING ACTIVITY[1]

ABSTRACT

Five steers aged 18 to 20 months and weighing 300 to 400 kg were offered five chemically and physically different feeds in a Latin square designed study with repeated observations (morning and afternoon). Energy cost of ingestion was calculated from the increased rate of oxygen uptake. The feeds were pelleted concentrate (50% barley grain, 40% alfalfa meal, 9% soybean meal, and 1% salt, trace mineral and vitamin supplement), pelleted alfalfa, alfalfa hay, chopped grass hay (70% brome, 30% fescue) and chopped fresh turnips. The pellets and hays contained approximately 90% dry matter while the turnips contained only 14% dry matter.

The rates of ingestion differed markedly among feeds during the limited (15 to 50 min) twice daily eating periods. On dry matter basis the pellets were consumed most rapidly at a rate of 130 to 138 g/min, while the hays were consumed at about 38 g/min and the turnips at 30 g/min.

The energy costs of ingesting feeds per minute spent eating were similar for all rations (27.6 to 35.6 joules/min/kg body weight. However, because of different rates of ingestion, the energy costs per kg of dry matter

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[1]This study was conducted primarily by the author and prepared as a scientific paper with coauthors B.A. Young, A.M. Nicol and A.A. Degen,University of Alberta, Edmonton. Canada.The findings were presented at the 71st. Ann. Meeting, Amer. Soc. Anim. Sci., Tucson, Arizona. July 28-August 1, 1979.(Amer. Soc. Anim. Sci. 71st. Ann. Meeting Abstracts, pp.353).

ingested per kg body weight were, for the pelleted feeds 222 to 238 joules, for the hays 1029 joules and for the turnips 1427 joules.

INTRODUCTION

The activity of feeding is a time-consuming venture especially for the free-ranging ruminant. The energetic cost of feeding has been well documented for sheep (Ustjanzew, 1911; Graham, 1964b, 1966; Young, 1966; Blaxter, 1967; Webster, 1967; Osuji, 1974; Osuji et al., 1975). More recently Holmes and associates (1978) have used a mobile hood to study the energy cost of feeding activity in grazing calves.

In view of the limited information available for cattle, the present study was undertaken to provide data on the energy costs to cattle of ingesting feeds which differ markedly in both physical and chemical form, and to determine the contribution to the total energy requirement of the animal arising from the cost of ingestion of each feed.

MATERIALS AND METHODS

Experimental Design

The study was a 5 x 5 Latin square design using five 18 to 20 month old cross-bred steers weighing 300 to 400 kg liveweight and five feeds (Table 2.1). Measurements of oxygen and feed consumption were taken on one animal each day during 3 h periods in the morning (08h30m to 11h30m) and afternoon (13h30m to 16h30m). When measurements were

Table 2.1. Physical form and chemical composition of feeds.

No.	Feed	Physical form	Dry matter (%)	Crude protein (% DM)	Acid detergent fiber (% DM)	Gross energy MJ/kg DM
1	Concentrate[1]	pelleted	87.1	15.3	13.7	18.3
2	Alfalfa	pelleted	90.3	12.2	33.8	18.3
3	Alfalfa	long hay	84.6	15.4	37.2	18.2
4	Grass[2]	chopped	89.4	11.3	39.4	18.4
5	Turnips	chopped	13.6	8.9	11.8	17.5

[1]Concentrate consisting of 50% rolled barley grain, 40% alfalfa meal, 9% soybean meal and 1% salt, trace mineral and vitamin supplement.

[2]70% brome grass, 30% fescue grass chopped to 2 to 7 cm lengths.

not being made the cattle were housed individually in straw-bedded stalls (4 m x 3 m). They were offered their daily maintenance ration (approximately 550 kJ/kg $.LW^{0.75}$: N.R.C., 1976) in two equal portions at 09h30m and 14h30m. Water and mineralized salt were available except when measurements were being made on an animal. The steers were weighed twice each week and were accustomed to the measurement procedures and the particular feed for at least one week prior to measurements.

Rates of oxygen consumption were measured using a ventilated hood with a capacity of 876 litres attached to a respiratory gas analysis system (Young et al. 1975). Air was drawn through the hood at a constant rate of between 245 and 250 litres/min and oxygen content of ingoing and outgoing air was analyzed (Taylor Servomex, Type OA.184 Sybron Corp., Sussex, England). During each test the animal was confined with its head contained in the hood for at least 30 minutes prior to feeding, for the feeding period of 15 to 50 minutes and for at least one hour post-feeding. Heat production was calculated using a caloric value of 20.5 kJ per liter of O_2 (McLean 1972).

The energy cost of ingestion was calculated from the increase in heat production (H) as:

H = (Heat production during feeding & recovery periods)
-(Average heat production during prefeeding & postfeeding periods)

The energy cost of ingestion was expressed either as the

increase in heat production per minute spent eating or the increase in heat production during feeding per kg of dry matter (DM) ingested per kg liveweight.

The data were analysed using least-squares analysis of variance for unequal numbers (Harvey, 1960). Differences among means were tested using Newman-Keuls' test (Steel and Torrie, 1960). Estimates of type 1 error were obtained as differences between animal x period interaction and treatment sum of squares.

RESULTS AND DISCUSSION

The effect of time of feeding (morning or afternoon) was not significant and the pooled results are reported. The rates and costs of ingestion of the feeds are summarized in Table 2.2 . On an as-fed basis the turnips with a high moisture content were consumed at a rate of 196 g per min which was not significantly different from 150 g per min for pelleted feeds. The hays however, were consumed at a rate of 40 to 43 g per min resulting in significant differences among feeds. When the rates of ingestion were expressed on a dry matter basis the turnips and hay diets were consumed at similar rates (Table 2.2) and were different ($P<0.01$) from the rate of consumption of pelleted feeds. In studies with 9-month old Friesian calves, Holmes et al. (1978) reported rates of ingestion of 20 g DM per minute for cut pasture (fresh and dried) and 14 g per min when calves were allowed to graze. Furthermore, the rate of eating was significantly

Table 2.2. Rates and costs of ingestion of feed by cattle.

No.	Feed	Rate of ingestion: As fed (g/min)	Rate of ingestion: Dry matter (g/min)	Cost of ingestion per kg liveweight: joules/min spent eating	Cost of ingestion per kg liveweight: joules/kg dry matter ingested
1	Concentrate pellets	149.3^{a}	129.7^{a}	27·6	237^{a}
2	Alfalfa pellets	149.9^{a}	137.9^{a}	28·9	218^{a}
3	Alfalfa hay	42.8^{b}	36.8^{b}	35·6	1029^{b}
4	Grass hay	39.1^{b}	38.8^{b}	27·6	776^{b}
5	Turnips	196.2^{a}	29.8^{b}	34·7	1428^{c}
SE of Means		15.0	10.1	3.5	113.6

^{a,b,c}Superscripts which differ within columns indicate means that are significantly different ($P < 0.05$).

related to liveweight in two out of six regressions. In our study , the steers were considerably heavier than the calves used by Holmes and co-workers, and individual animal differences were not significant possibly because of the similar background and treatment given to the animals prior to and during the study. However individual animal differences in, for example, bite size or appetite, could influence rate of ingestion of feeds. Comparison of results from sheep with those from cattle (Table 2.3) tends to emphasize species, feed type and possibly management situation differences with regard to the rate of ingestion.

The energy cost of ingestion was similar for all feeds when expressed on the basis of joules per min spent eating per kg liveweight (Table 2.2). The values of 27.6 to 35.6 joules per min spent eating per kg liveweight were similar to the value of 29.5 reported for cattle by Dahn (1910) as cited by Osuji (1974), and the energy cost to calves of consuming several types of feeds (Holmes et al., 1976). Furthermore, the values (summarized in Table 2.3) are similar to those reported for sheep (Ustjanzew, 1911; Graham, 1964b; Young, 1966; Webster and Hays, 1968; Osuji, 1974). The fact that the energy cost of consuming a wide range of rations was similar when expressed as joules per minute spent eating per kg liveweight, irrespective of the species or rate of ingestion, supports the conclusion of Holmes et al. (1978) that energy expenditure during eating or grazing by animals was relatively constant per kg live-

Table 2.3 Comparison of the present estimates of the rates and costs of ingestion by cattle with published data for cattle and sheep.

Animal	Age (months)	Weight (kg)	Feed	Rate of ingestion (g dry matter/min)	Cost of ingestion (per kg liveweight) (joules/min)	Cost of ingestion (per kg liveweight) (joules/kg dry matter)	Source
Ox	?	?	Hay	?	29.5	?	Dahn (1910) cited by Osuji (1974)
Jersey calves	1.5 to 7.5	55 to 122	Pelleted meal	?	27.8		
			Hay		19.5	?	Holmes et al. (1976)
			Grazed grass		31.3		
Friesian calves	9	117 to 144	Dried grass	20	39.7	1948	Holmes et al. (1978)
			Fresh grass	21	39.7	1948	
			Grazed grass	14	46.9	3652	
Crossbred steers	18 to 20	298 to 407	Concentrate pellets	129.7	27.6	237	Present data
			Alfalfa pellets	137.9	28.9	218	
			Alfalfa hay	36.8	35.6	1029	
			Brome/fescue hay	38.8	27.6	776	
			Turnips	29.8	34.7	1428	
Adult sheep			Chaff and grass hay	4 to 18	39±13.7†	5523±1589†	Summarized from various sources
			Pelleted and grain concentrates	8 to 80	39±13.7†	1658± 715†	

† Standard deviation of mean

? Unknown

weight. Osuji (1973) as cited by Osuji (1974) also reported that the energy cost of eating in sheep varied directly with the time spent eating.

When the energy cost of ingestion was expressed on the basis of kg DM ingested there were marked differences among feeds (Table 2.2). The pelleted feeds cost only 222 to 238 joules per kg DM per kg liveweight while the cost of ingestion of the hays and turnips were three to six times (778 to 1427 joules /kg DM/kg liveweight) these values. Because cattle ingest feed more rapidly than sheep the cost of this activity, when expressed on a DM intake basis was very much less for cattle (Table 2.3). Calves tend to expend about twice the energy in ingesting grass than young adult cattle.

The contribution of the energy cost of ingestion to the daily energy requirements of cattle is summarized in Table 2.4. While the cost of ingestion for the different feeds represented a 15 to 70% increase in energy expenditure while the animal was actually eating, this cost was only about 1% of the total daily energy expenditure for the pelleted ration, 3.8% for the grass hay and turnips and slightly over 5% for the long alfalfa hay . Calculations by Holmes et al. (1978) indicate that the energy expenditure due to eating could account for 0.1 to 2% of the ME of high-quality feeds and for 1.3 to 15.7% of the ME of low-quality feeds. Maintenance energy requirements for the grazing animal have been reported to be 25-100% above that for similar penned

Table 2.4. Estimated daily energy expenditure attributable to the cost of ingestion for a 400 kg steer.

No.	Feed	Daily dry matter intake (kg)	Percent of total energy expended attributable to the cost of ingestion (%)
1	Concentrate pellets	4.5	0.9
2	Alfalfa pellets	6.1	1.1
3	Alfalfa hay	6.5	5.4
4	Grass hay	6.2	3.8
5	Turnips	3.9	3.8

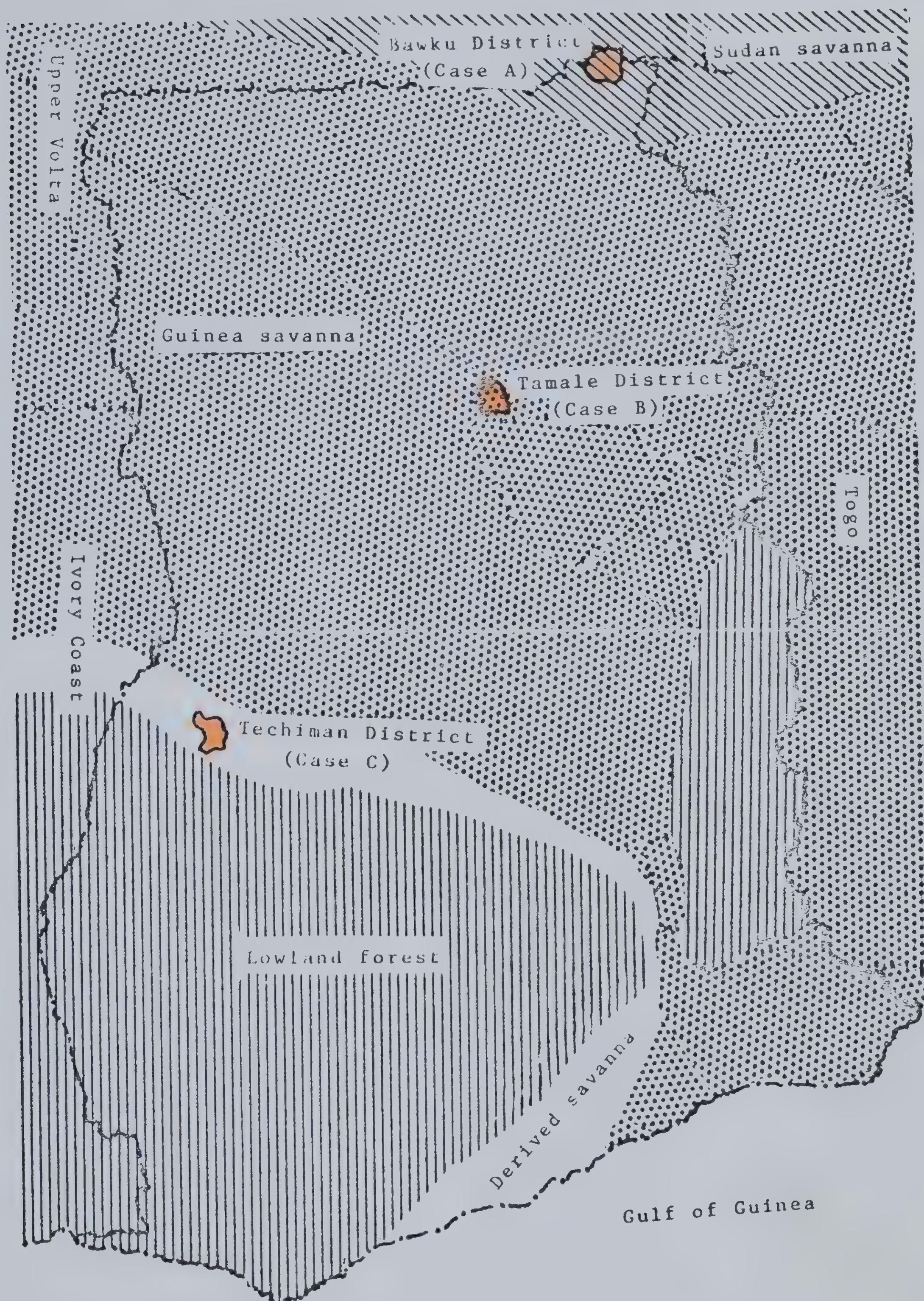
animals (Langlands et al., 1963; Hutton, 1962, Lambourne and Reardon, 1963). Thus, for the range animal which must spend considerable time to obtain its feed, a greater portion of its daily energy requirements is likely to be expended not only in locomotion but also in ingestion of feed. Furthermore, feeds with high energy costs of ingestion increase the metabolic heat load. In hot environments, adoption of management practices and feeds which reduce an animal's heat production could therefore be of considerable advantage. For example, for cattle consuming long poor quality grass or hay the cost of ingestion and heat production would be much greater than when comparable amounts of pelleted or concentrate diets are consumed.

3. CASE STUDIES

3.0.0.1 Introduction

The area covered by savanna vegetation in West Africa is extensive (Figure 1) and variations in local conditions within the different vegetative zones are partly due to edaphic and biotic factors. The overriding factor influencing the gross delineation into the various vegetative zones is climate. Rainfall is the vital element the distribution of which closely follows the vegetation zones (Keay, 1959). Some of the coastal rainforest areas receive over 2500 mm of annual rainfall but areas along the 15° latitude may get only 250 mm of rainfall (Thompson, 1965). The amount and variability of rainfall influence plant growth and therefore, the quantity and quality of potentially available feed for grazing cattle. Other factors such as management practices, the incidence of animal pests and diseases and stresses imposed on animals by the environment collectively influence the productivity and efficiency of cattle. The genetic potential of the breed of cattle also is important. In order to examine quantitatively the influence of environment and management on productivity of cattle in the savanna areas of West Africa three areas in Ghana will be treated in the nature of case studies. The selected districts of Bawku, Tamale and Techiman occur, respectively, in the Sudan, Guinea and Derived Savanna zones of Ghana (Figure 2). The naming of the districts for each case study is in accord with a major town or center of the

Figure 2. Vegetation zones of Ghana and case study districts



region. The Guinea Savanna is the largest of the three vegetation types in Ghana but this is not the situation in the other West African countries (Figure 1).

The three areas for case study were selected to represent the range of savanna type in Ghana. Some climatic variables which distinguish the different areas are plotted in Figure 3. In the Bawku and Tamale districts rainfall occurs in a single period (April to October) with a peak in August or September. Rainfall in the Techiman district is bimodal with a major wet season occurring between March and June or July, and a minor wet season falling between September and November. Thus whereas the Derived savanna zone is blessed with 7 to 8 months with rainfall of over 80 mm per month the Guinea zone and some southern portions of the Sudan zone (for example, Bawku) have only 6 rainy months and the number of rainy months decreases as one proceeds northwards. The number of rain-days per year follows the monthly rainfall pattern (Figure 3) and the mean annual rainfall in millimetres for the Bawku, Tamale and Techiman districts are 956, 1084 and 1345, respectively (Ghana Meteorological Services Climatological Tables, 1972; Agricultural Extension Handbook (Ghana). Monthly relative humidities are high during the wet season and low during the dry season, the low values being more pronounced in the Tamale and Bawku districts than in the Techiman area. Monthly maximum and minimum temperatures are, however, much higher in the Bawku and Tamale districts as compared to the

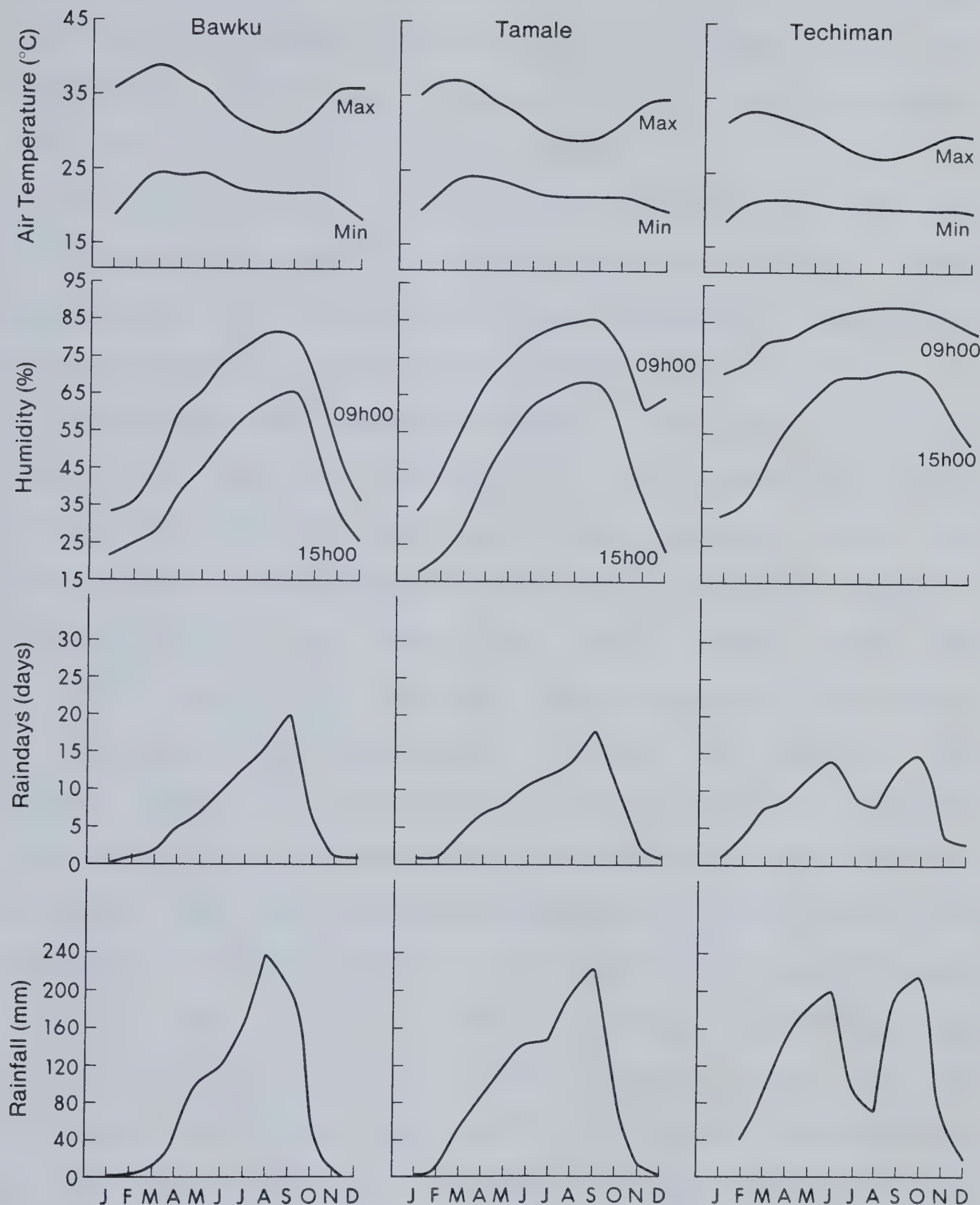


Figure 3. Climatic conditions of the case study districts of Bawku, Tamale and Techiman.

Techiman district (Figure 3). The annual average temperatures among the different vegetation zones in Ghana are however similar and are 28.1°C for Bawku, 27.8°C for Tamale and 25.7°C for Techiman (Ghana Meteorological Services Climatological Tables, 1972).

In addition to the climatic differences in the case study areas there are variations in social practices, breed composition of cattle herds and management practices, pasture composition and seasonal water resources.

There are very few measurements of the pasture species composition and the quantity of feed consumed by grazing cattle in the West African savanna zone. Reports about the composition of natural grasslands are mostly qualitative in nature (Rattray, 1960; Rose-Innes, 1962; Whyte, 1974) and the few quantitative ones have been related to the effects of burning and have invariably excluded the role of the grazing animal in influencing species composition (Ramsay & Rose-Innes, 1963). It would be desirable to be able to estimate the total nutrient intake of grazing cattle from knowledge of the proportions of different species of herbage consumed, what parts of plants are eaten, the chemical and physical characteristics of the composite diet and the efficiency with which the feed is utilized by the animal to provide usable nutrients. Estimates of feed quality in terms of dry matter, crude protein and crude fiber contents will be presented in each case study situation and further estimates made of the diet consumed by cattle during the wet

and dry seasons. Also estimates of daily dry matter intake and hence intake of metabolisable energy (ME) and apparently digested crude protein (DCP) will be considered.

Following a description of each district and the conditions existing that affect cattle raised from natural grasslands, an energy budget analysis is presented for typical cattle during the wet and dry seasons. A brief description is first given of the method of energy budgeting then, for consistency in presentation, each case study district will be considered in the following format:

a) a short introduction giving details of each location and the characteristics of cattle management;

b) the climatic environment and how it relates to the vegetation zone;

c) the non-climatic and other background information such as farming practices, dry season fires, incidence of tsetse flies;

d) estimates of feed quality, diet composition and daily feed intake during the different seasons. Discussion of the basis of these estimates is included;

e) estimates of daily animal activity during each season and a discussion of the basis of such estimates;

f) an energy budget calculated for a typical animal, a non-pregnant 3-year-old heifer.

Following the consideration of all three cases there is a general discussion and an overall interpretation of the findings.

3.0.1 The Energy Budget

The balance between the factors which contribute to the energy intake by animals and their energy utilization influences the growth pattern of animals. During the estimation of energy budgets of animals kept indoors and in conditions close to thermoneutrality the effects of the environment are minimal. Under field conditions radiation levels could be considerable and the environment is continually changing with regard to wind speed and direction, relative humidity and radiation fluxes. (Robertshaw and Finch, 1976). Calculation of the energy budget excludes the direct influences of the climatic conditions on the animals. Assessment of the energy budget includes measurement of feed intake, the efficiency of its utilisation for maintenance of body integrity and doing work and the efficiency of its utilisation for protein and fat deposition and the synthesis of other products.

A number of assumptions will be made in calculating the energy budget for a typical animal in each of the case study districts. It has been assumed that the energy utilized for maintenance and in activities such as standing, walking, grazing and ruminating account for the difference in metabolisable energy (ME) intake and ME content of daily

liveweight gain or loss. As the energy value of liveweight gains by West African Shorthorns and Sanga cattle (the breed and crossbreed that will be used in the calculations) have not been determined, an average value for cattle of 20 MJ of ME per kg of gain is used (A.R.C., 1965; M.A.F.F., 1975; Webster, 1978). The same value also is used in calculations relating to liveweight loss. In the concluding discussion, results arising from the calculations and possible consequences of the assumption will be considered in relation to observed liveweight gains and losses by cattle.

3.0.2 CASE A: BAWKU DISTRICT

3.0.2.1 Introduction

Bawku is a town of about 25,000 inhabitants and it is situated in the north-eastern corner of Ghana (latitude 11° 03′ N and longitude 00° 16′ W). The vegetation is described as Sudan savanna woodland (Keay, 1959) and the area covered by this vegetation type is approximately 1955 square kilometers (Lane, 1962; Figure 2). The township of Bawku is approximately 230 meters above mean sea level (Ghana Meteorological Services, 1972). The Sudan savanna belt in West Africa is some 75 to 150 km from north to south and stretches from the Senegal coast through Nigeria to the Sudan and beyond (Crowder & Chheda, 1977; Figure 1). Throughout the sudan savanna it is densely populated with cattle, mainly of the humped Zebu type. Compared with other parts of Ghana, the Bawku district has a very high density of Zebu type cattle and crosses between the Zebu and other local breeds such as the West African Shorthorn and the N'Dama. Some characteristics of cattle breeds and crossbreeds in Ghana are summarized in Table 3.1. The age of Sanga cattle at first calving is between 3 and 3.5 years. This is similar to that of other breeds in the Bawku district and the Sudan savanna. The heavier calf birthweight of the Sanga crossbreed is closer to that of its White Fulani sire than to its West African Shorthorn dam. Female

Table 3.1. Characteristics of cattle breeds in Ghana[1].

Breed	Age at first calving (years)	Average weight (kg)						
		Birth	1 Year		2 Years		3 Years	
			Male	Female	Male	Female	Male	Female
West African Shorthorn	3.5 to 4.0	18 to 20	109	82	164	136	193	173
N'Dama	3.0 to 3.5	19	105	105	129	162	261	220
White Fulani	3.0	22 to 25	135	134	182	178	257[2]	229[2]
Sanga (White Fulani bull x West African Shorthorn cow)	3.0 to 3.5	24	125	120	251	239	330	307
Sokoto Gudalli	3.5	24 to 30	153	143	269	229	541	334

1. From Walker (1967).
2. Weight at 30 months.

Sanga cattle weigh a little over 300 kg at 3 years of age as compared to about 170 kg by West African Shorthorns. Male cattle generally weigh heavier than females at all ages. A Sanga heifer will be used in calculations related to the daily energy budget of cattle in the Bawku district.

3.0.2.2 Climatic Environment

The general climatic conditions of the Bawku area are summarized in Figure 3. Details of climatic parameters are presented in Table 3.2. Because of its tropical location, daily temperatures are high and mean monthly maximum temperatures vary from 30 to 40°C with an annual mean maximum of 34.6°C. Monthly minimum temperatures are about 11°C below maximum temperatures with the lowest minimum temperatures occurring during the months of November to January. This period is the harmattan season during which hot, dry and dusty northeasterly winds from the Sahara desert, blow over the region. Relative humidities are very low during the harmattan season (Table 3.2).

The months of April to October are relatively more humid and relative humidity at 09h00m increases from 61% at the beginning of the wet season in April, reaches a peak of 82% in August and then drops off sharply in mid-October at the end of the rainy season. Relative humidities at 15h00m fall into an identical pattern as those at 09h00m but values are generally lower in the afternoon. There are 82 days in

Table 3.2. Climatic data of the Bawku District.

Month	Air temperature (°C)			Humidity[2] (%)		Raindays[2] (days)	Rainfall[2] (mm)
	Max.[1]	Min.[1]	Mean.[2]	09h00	15h00		
Jan.	36.0	19.1	27.4	34	22	0[3]	0
Feb.	37.9	22.5	28.5	36	25	1	4
Mar.	38.8	24.7	31.4	46	28	2	14
Apr.	37.4	24.5	31.3	61	39	5	46
May	35.6	24.5	30.2	66	45	7	102
Jun.	32.5	23.0	28.0	74	54	10	118
Jul.	30.9	22.5	25.6	78	60	13	165
Aug.	29.8	22.1	26.0	82	64	16	238
Sep.	30.9	22.0	26.3	81	66	20	200
Oct.	33.4	22.2	27.6	69	51	6	60
Nov.	36.2	20.5	28.5	49	34	1	8
Dec.	35.8	18.5	27.3	37	26	1	1
Mean	34.6	22.2	28.1	59	42		
Total						82	956

[1]Temperatures are derived from climatological tables (1962 to 1972, excluding 1970), Ghana Meteorological Services, 1972.

[2]20 to 60 year data from the Agricultural Extension Handbook (1977), Ghana.

[3]Days with 0.25 mm or more of rainfall.

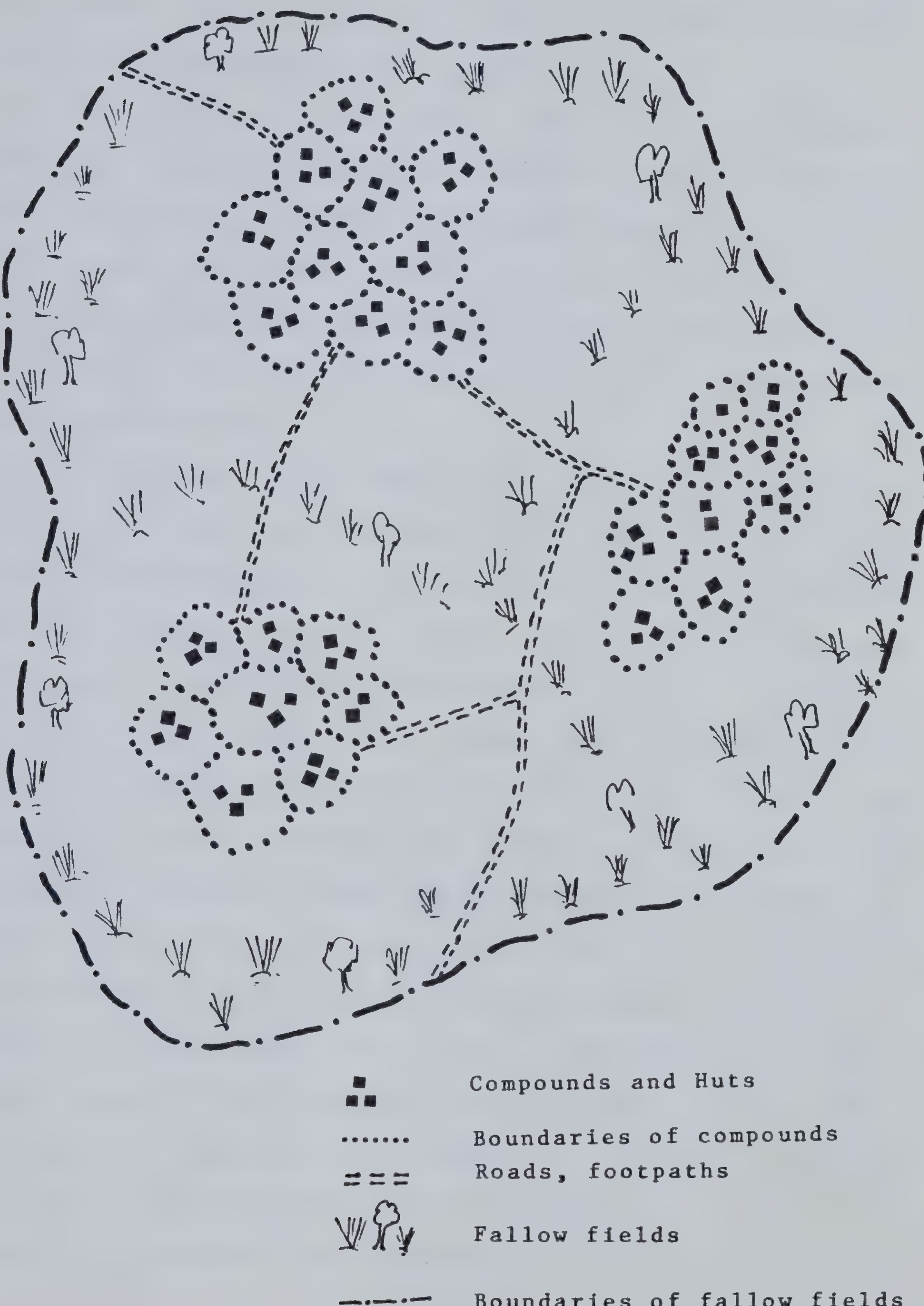
the year that are classified as receiving 0.25mm of rainfall or more in a day (Agricultural Extension Handbook (Ghana), 1977) and the number of raindays roughly parallels the amount of rainfall received per month (Table 3.2). The wettest months are August and September which record 238 and 200mm of rainfall, respectively. Five months (November through March) receive insignificant amounts of precipitation.

Benneh (1971) has calculated that the Bawku district has a mean annual rainfall deficiency of 813 mm; that is, the difference between precipitation and evaporation is a negative value of 813 mm and this has serious consequences for crop growth and for animal production. The annual dependable rainfall is approximately 762 mm (Ussher,1969) and almost all of this falls in the wet season (Figure 3.3; Table 3.2). Solar radiation levels are quite high with daily means of 1.9 kJ per cm^2 (Ussher, 1969). This is associated with bright sunshine hours averaging 7.2 hours/day during the wet season and 8.6 hours/day during the dry season. The average day has about 12 hours of daylight and this does not vary very much over the year (Ussher, 1969).

3.0.2.3 Non-climatic and Other Background Information

Population density in the Bawku district varies between 80 and 150 persons per Km^2 (Benneh,1971) and settlements are in the form of compound houses surrounded by the compound farm (Lane, 1962). Figure 4 diagrammatically illustrates the

Figure 4. Illustration of settlement type in the Bawku Distric



typical settlement arrangement. At the outskirts of the compound farming area there are a few 'distant' farms and old grassy fallows comprised mainly of short grasses and short trees and shrubs (Wills, 1962).

Land tenure in the Bawku district is by communal ownership. Grazing grounds are therefore communal and made up of the old fallows and uncultivated tree savanna (Wills, 1962). Water may become scarce in the dry season and cattle are then driven to distant grazing grounds in search of feed and water. This practice is widespread in all parts of the Sudan savanna zone.

Of the trees in the Bawku district, the most common are *Acacia spp* and economically useful trees such as Dawadawa (*Parkia clappertoniana*, Keay) and Shea butter (*Butyrospermum parkii*, Kotschy) (Wills, 1962). The grass genera include *Andropogon, Hyparrhenia, Pennisetum, Cynodon, Loudetia, Aristida* (Rose Innes, 1962). Under the grazing system that prevails, cattle are driven to graze the annual and perennial fallows during the cropping season and then allowed to forage on fields which have been harvestered of their grain during the early dry season but are driven to more distant fallows as the dry season advances. Cattle are bedded in enclosures or kraals in the evenings and their dung is used to fertilize the compound farms (Wills, 1962). The use of bullocks to plough the fields is a common practice in this district and in 1974 bullocks accounted for 21% of all cattle in the Bawku area (Ministry of Agriculture

(Ghana), 1975).

Crops cultivated include early and late millet (*Pennisetum typhoides* Stapf and Hubbert), guineacorn or sorghum (*Sorghum vulgare*), groundnuts (*Arachis hypogaea*), upland rice (*Oryza sativa*) and bambara beans (*Voandzeia subterranea* Thouars). Some residues of these crops are consumed by cattle but the soils are low in fertility which may contribute to a poor nutritive value of the residue. Soils are mainly Savanna ochrosols and groundwater laterites with a humus content of usually less than 2% (Brammer, 1962). In eroded places hard iron pan is reported to occur at or within 3 to 5 cm of the surface.

The very dry conditions and sparse vegetation of the Sudan savanna do not encourage the spread of tsetse flies (*Glossina spp.*), the insect vectors of Trypanosome parasites. Trypanosomiasis is therefore not a significant problem in these areas.

Both controlled and uncontrolled burning of the grassland is practised in all parts of the savanna zone and Ramsay and Rose-Innes (1963) argue that because of legislation that prohibited the starting of fires in the Bawku district, fires that occurred would be of the late dry season type that favoured the growth of short grasses and the destruction of woody species. There have been various reports on the merits and demerits of savanna bushfires. Among the positive aspects are the destruction of harsh unpalatable grasses and the provision of fresh nutritious

herbage for livestock. Encroachment by unwanted woody species is also kept under check. The negative aspects of dry season fires are that much of the standing hay is destroyed and animals may be faced with scarce feed sources; burning prevents the accummulation of humus in the soil and thereby increases soil infertility; soil may be unfavourably affected by leaving it exposed to the direct effects of wind, sun and rain.

3.0.2.4 Estimates of Feed Quality, Diet Composition and Intake

Table 3.3 summarizes data from Rattray (1960), Whyte (1974), Bogdan (1976), Rose-Innes (1962) and Ramsay & Rose-Innes (1963) of the occurrence of the principal fodders. The most frequently encounted grass species is *Andropogon gayanus* or Gamba grass. Species of *Pennisetum, Cynodon, Hyparrhenia* and *Loudesia* assume varying proportions at different seasons of the year. Four leguminous trees and shrubs are given and these are present throughout the year. Acacias are the most important and both leaves and pods are good dry season feed supplements. Of the seasoning plants or forbs only two species, examined by Boudet (1970), are included. Bulrush millet (*Pennisetum typhoides*), Sorghum (*Sorghum vulgare*) and Groundnuts (*Arachis hypogaea*) are the common crops cultivated in the Bawku district. Residues of these crops are usually available to cattle during the dry season. There is a wide variation in the contents of dry

Table 3.3. Principal fodders and estimates of feed composition (weighted averages of available fodders) available to cattle in the Bawku District - Wet season.

	Grasses	Legumes	Forbs
Principal fodders	*Androgogon gayanus vars**** *Andropogon pseudapricus** *Pennisetum pedicellatum*° *Cynodon dactylon*° *Hyparrhenia subplumosa**	*Acacia albida*° *Afzelia africana*° *Bauhinia rufescens*° *Pterocarpus erinaceus*°	*Borreria stachydea*° *Jacquemontia tamnifolia*°
Composition			
Dry matter, (%)	30 (25-50)	35 (30-45)	27 (20-35)
Crude fiber, (%)	30 (25-40)	22 (18-28)	25 (20-35)
Crude protein, (%)	8 (6-11)	13 (11-18)	9 (7-12)

Percent of species available to animal: *** >50%; ** 30-50%; * 5-30%; ° <5%

Table 3.3. (continued) Early dry season.

	Grasses	Legumes	Forbs	Crop residues
Principal fodders	*Andropogon gayanus vars.*** *Hyparrhenia subplumosa*** *Digitaria spp.** *Brachiaria spp.** *Aristida hordeacea*°	*Acacia albida*° *Afzelia africana*° *Bauhinia rufescens*° *Pterocarpus erinaceus*°	*Borreria stachydea*° *Jacquemontia tamnifolia*°	*Spiked millet*° *Sorghum*° *Groundnut haulms*°
Composition				
Dry matter (%)	50 (35-55)	35 (30-40)	33 (25-38)	47 (20-85)
Crude fiber (%)	35 (30-42)	22 (18-26)	28 (22-33)	30 (27-40)
Crude protein (%)	5 (3-6)	14 (11-18)	6 (4-8)	5 (3-10)

Percent of species available to animal: *** >50%; ** 30-50%; * 5-30%; ° <5%

Table 3.3. (continued) Late dry season.

	Grasses	Legumes	Forbs	Crop residues
Principal fodders	*Andropogon pseudapricus*** *Hyparrhenia spp.*** *Aristida hordeacea** *Heteropogon contortus** *Eragrostis superba*°	*Acacia albida*° *Afzelia africana*° *Bauhinia rufescens*° *Pterocarpus erinaceus*°	*Borreria stachydea*° *Jacquemontia tamnifolia*°	*Spiked millet*° *Sorghum*° *Groundnut haulms*°
Composition				
Dry matter (%)	75 (25-90)	35 (30-45)	34 (20-50)	55 (25-90)
Crude fiber (%)	35 (25-40)	24 (18-26)	28 (20-35)	32 (25-40)
Cruce protein (%)	4 (2-6)	13 (11-18)	7 (5-10)	5 (2-9)

Percent of species available to animal: *** >50%; ** 30-50%; * 5-30%; ° <5%

matter, crude fiber and crude protein in all groups of fodders and during the wet or dry seasons (Table 3.3). This is probably a reflection of different leaf to stem ratios, the stage of maturity, proportions of particular fodder species and variations in local conditions especially soil fertility. The value of the particular parameter such as dry matter (DM), crude fiber (CF) or crude protein (CP) of the diet actually consumed by a cow is an estimated average (Table 3.3.). This value is based on the published range of values (in parenthesis in Table 3.3), the extent of the opportunity to select desirable species by the cow and the fact that grazing animals will select herbage of a better nutrient value than the average of the pasture (Gohl, 1975). Thus during the wet season, the dry matter content of feed consumed is estimated at 30%, and CF and CP are 30 and 8%, respectively. During the subsequent early dry season DM, CF and CP contents are 50, 35, and 5%, respectively, and further into the late dry season the DM increases to 75%, CF is unchanged at 35% and CP falls to 4%. Estimated values of DM, CF and CP of legumes during the wet season are 35, 22 and 13%, respectively (Table 3.3). These estimates do not change very much during both the early and late dry seasons since these species are able to remain green during the dry season (Rose-Innes, 1966) and a fresh growth of leaves replaces those that fall off after bush burning. Forbs are relatively more succulent than grasses or legumes and the estimated DM values increase from 27% to 33% and again to

34% during the wet season , the early dry and the late dry seasons, respectively. The CF content of forbs is less than that of grasses but slightly more than that of legumes; however, CP content is lower than the estimates given for the legumes but identical with values for grasses (Table 3.3). Crop residues are available in usable quantities only during the early and late dry seasons and the DM content also increases as the dry season advances. The CP content is very low (5%) and comparable to that of grasses during the same period.

Grass is the main component of the feed consumed by grazing cattle comprising at least 75% of pasture plants found in the rumen of slaughtered cattle (Chippendale, 1964). Legumes and forbs form only a small constituent of the total diet of grazing cattle largely because these plants occur naturally in very low frequencies (Rose-Innes, 1966; Chippendale, 1964). In the Bawku area crop residues may comprise as much as 10% of daily DM intake especially during the early dry season. Based in part on the work of Chippendale (1964) and composition and quality of feed summarized in Table 3.3, a composite diet with estimated proportions of grasses, legumes, forbs and crop residues was formulated for a 3-year-old, non-pregnant Sanga heifer (Table 3.4). I have assumed that under both the kraaling and free range management systems the feed composition is the same because of the limited scope of selection by cattle during the dry season. Crude fiber increases from a value

Table 3.4. Estimated diet composition (weighted for proportions of principal fodders) and daily feed and nutrient intake in the Bawku District.

Season	Wet	Early dry		Late dry	
Management system	Kraaled	Kraaled	Free-range	Kraaled	Free-range
Feed composition					
Crude fiber (%)	29.4	33.5	33.5	33.3	33.3
Crude protein (%)	8.3	5.5	5.5	5.0	5.0
Digestible energy (MJ/kg)	9.2	8.3	8.3	8.3	8.3
Metabolisable energy (MJ/kg)	7.5	6.8	6.8	6.8	6.8
Daily feed intake					
Dry matter (kg)	8.1	6.6	7.5	6.0	7.0
Digestible energy (MJ)	74.6	55.2	62.8	50.2	58.5
Metabolisable energy (MJ)	61.2	45.3	51.5	41.2	48.0
Crude protein (g)	747	413	446	300	345
Digestible crude protein(g)(a)	318[1]	90	102	54	63
(b)	376[1]	144	164	105	122

[1]Estimated intake based on (a) McDonald et al. (1973), and (b) NRC (1976).

of 29.4% in the wet season to slightly over 33% in the late dry season. There is a concomitant decrease in crude protein from 8.3% to 5.0% (Table 3.4). Summarized in Table 3.4 also are estimates of daily dry matter intake, the energy density of the diet, ME intake and the intake of digestible crude protein.

Estimates of dry matter intake per day by cattle in the West African zone range from 2 to 3 percent of liveweight (Crowder & Chheda, 1977; Antwi & Addei, 1977). These values are based on the clipping technique and thought to be overestimated by 15 to 25% when intake is estimated by the nitrogen-chromic oxide faecal index technique (Olubajo, 1970). Consequently, maximal voluntary intake in the wet season is assumed to be 2.7% of liveweight, that in the early dry season is 2.2% for kraaled cattle and 2.5% for free-range cattle; corresponding percentages for the late dry season are 2.0 and 2.3 percent. Within the lowland tropics, 3 to 5 weeks regrowths of grasses are 55 to 70% digestible with reference to their dry matter (Crowder & Chheda, 1977). The digestibility of the DM of legumes may be very high (Rose-Innes, 1966) but given the very low fertility of the soils in the Bawku district and digestibility values of the predominant herbage species in the region the following digestibility of DM values (% of DM) are assumed:

	Grasses & Crop Residues	Forbs & Legumes
Wet Season	55	60
Early Dry Season	50	55
Late Dry Season	45	50

The gross energy contents of the composite diets were not very different from season to season and an average value of 18.4 MJ per kg DM was used to calculate digestible energy (DE) from which ME was obtained from the relation, ME = DE x 0.82 (A.R.C., 1965). Apparently digested crude protein (DCP) was calculated from two sources (NRC, 1976 and McDonald et al., 1973). The values obtained from these sources are compared with minimum requirements for maintenance and moderate growth (A.R.C., 1965)(Table 3.4). Under kraaling a 300 kg heifer ingested 61 MJ of ME per day and this fell by 26% in the early dry season to 45 MJ and by 33% in the late dry season. Corresponding ME intake under free-range conditions were 61, 52 and 48 MJ. Under kraaling DCP intake per day (g) estimated by the method described by McDonald et al. (1973) was 318 during the wet season, 90 during the early dry season and only 54 during the late dry season. Free-range cattle consumed 102 and 63 g during the early and late dry seasons, respectively. Estimates by the NRC (1976) are much higher than these values especially for the late dry season where they are about 200% but still less than the minimum A.R.C. (1965) requirements for maintenance (Table

3.4).

3.0.2.5 Estimates of Daily Amounts of Animal Activities

For animals that forage to obtain almost all their daily intake of nutrients, the cost of such activities could become significant especially in times of drought and feed scarcity. Among the activities cattle do each day, the most significant ones are standing, walking, grazing or eating and ruminating. There are very few quantitative studies of such activities in West Africa. In the Sudan savanna, nomadism is the major mode of raising cattle and herdsmen drive their animals over extensive areas in search of feed and water (Oyenuga, 1966; Oyenuga et al., 1971). Cattle in the Bawku district form an integral part of this seasonal activity of grazing livestock but grazing management is not nomadic. It is a mixture of night-enclosure (or kraaling) of animals after the day's grazing during the wet season and also during the dry season. In certain parts of the district, however, a system prevails whereby cattle are left to graze without herding (free-range) during the subsequent dry season.

Estimates of the amounts of daily activities by cattle in the Bawku vicinity are summarized in Table 3.5. These estimates are a composite of values reported in the literature for both the West African savanna areas and identical climatic regions in East and South Africa where native cattle management practices are not essentially

Table 3.5. Amounts of daily activities of cattle in the Bawku District.

Season	Wet	Early dry		Late dry	
Management system	Kraaled	Kraaled	Free-range	Kraaled	Free-range
Activity per day					
Standing (h)	18	18	19	18	19
Walking (km)					
Forced walking[1]	3	8	0	13	0
Voluntary walking[2]	4	6	10	6	18
Grazing (h)	7.5	6.5	10	5.5	10
Ruminating (h)	6	6	7	6	7

[1]Average walking speed approximately 4 km/h.

[2]Average walking speed of between 0.3 and 0.6 km/h.

different (Smith, 1962; Smith, 1970; Rose-Innes, 1963; 1966). The author's personal observations were also used in the derivations of these estimates. In Table 3.5, walking is separated into two components, *viz.*, forced and voluntary walking. Forced walking refers to the distance walked by cattle from the village to the grazing grounds, from the grazing grounds to watering points and back to the grazing grounds and thence to the village. During part of this journey cattle do manage to graze but it is assumed that the speed of walking (taken as 4 km/h) prevents them from ingesting more than 20% of daily DM intake. Voluntary walking is the total distance traversed by cattle during the act of grazing which involves walking short distances between bites of tussock grasses.

For kraaled cattle the distance walked per day under forced walking is 3 km during the wet season, increases to 8 km during the early dry season and is four times as much (13 km) during the late dry season (Table 3.5). Voluntary walking correspondingly increases from a value of 4 km in the wet season to 6 km during the early dry season but thereafter remains unchanged. The increasing distances are a reflection of a combination of factors, the most relevant of which are the deteriorating quality of available forage and the cow's attempt to select nutritious components, and an absolute scarcity of feed that results from the uncontrolled burning of highly inflammable dry grasses. Free-ranging cattle also increase the distance they have to travel (18 km

in the late dry season) in order to graze and water but this also results in an increased DM intake from 6.0 to 7.0 kg (Table 3.4). Standing occupies about 80% of a grazing animal's day and 18 to 19 hours are spent in this activity during the different seasons and management systems. Part of this time is used in grazing activity, the number of hours decreasing from 7.5 in the wet season to 5.5 in the late dry season under kraaling management (Table 3.5). With kraaling, cattle are normally sent out to graze at about 08h00m and returned to the kraal at sunset (18h00m). Cattle under this system of management therefore have only 10 hours for grazing and associated activities. Free-ranging cattle are not subject to this restriction and are able to increase their grazing time from 7.5 to 10 hours per day. The number of hours spent ruminating does not vary much, reflecting the general bulkiness of the feed, and is between 6 and 7 hours per day in all seasons (Table 3.5).

3.0.2.6 Daily Energy Budget for a 3-year-old, Non-pregnant Sanga Heifer

The Sanga is the cross between the Ghana Shorthorn and zebu. For example, the White Sanga is a cross between the White Fulani and the Ghana Shorthorn or West African Shorthorn. The characteristics of the Sanga and White Fulani are very similar (Table 3.1) and the Sanga is chosen to represent cattle of the Sudan savanna zone. This zone has a predominant Zebu cattle population of which the White Fulani

is the most numerous (Oyenuga,1967). A 3-year-old heifer is assumed to have reached puberty since the age at first calving is 3.5 years. The procedure involved in the calculation of the energy budget has been outlined in the introductory section (page 39). Preferred values of the energy costs of activities are presented in Table 1. The amounts of daily activities and the intake of dry matter and ME by cattle in the Bawku district are summarized in Tables 3.5 & 3.4.

The estimated daily energy budget is given in Table 3.6. A constant liveweight of 300 kg is assumed and daily maintenance requirement of ME is taken as 468.$LW^{0.75}$ MJ per day (A.R.C., 1965). The ME content of liveweight gain or loss is assumed to be 20 MJ/kg. The results show that under kraaling management, energy expenditure involved in all activities represented 30%, 35% and 37% of the combined maintenance and activity costs during the wet season, early dry season and late dry season, respectively. Corresponding values for free-range conditions are 30%, 36% and 41% (Table 3.6). When the activity costs are expressed as percentages of daily ME intake in the case of kraaled cattle it is seen that 23%, 39%, and 49% of daily ME intake is utilized in activity during the wet, early dry, and late dry seasons, respectively. For free-ranging cattle, the corresponding values are 23%, 36% and 49%. Consequently, cattle consume enough feed and expend relatively little of the ingested energy in activities during the wet season.

Table 3.6. Daily energy budget for a 3-year-old non-pregnant Sanga heifer in the Bawku District.

Season	Wet	Early dry		Late dry	
Management system	Kraaled	Kraaled	Free-range	Kraaled	Free-range
Weight of animal (kg)	300	300	300	300	300
Daily intake					
Dry matter (kg)	8.1	6.6	7.5	6.0	7.0
Metabolisable energy (MJ)	61.2	45.3	51.5	41.2	48.0
Daily output					
(a) Maintenance (MJ)	33.8	33.8	33.8	33.8	33.8
(b) Activity (MJ)	14.3	17.9	18.7	20.2	23.7
Standing	1.8	1.8	1.9	1.8	1.9
Forced walking	1.9	5.0	0.0	8.2	0.0
Voluntary walking	2.5	3.8	6.3	3.8	11.3
Grazing	6.3	5.5	8.4	4.6	8.4
Ruminating	1.8	1.8	2.1	1.8	2.1
Total (a+b) (MJ)	48.1	51.7	52.5	54.0	57.5
Estimated daily balance					
Energy balance (MJ)	+13.1	-6.4	-1.0	-12.8	-9.5
Weight gain (kg/day)	+0.7	-0.3	-0.1	-0.6	-0.5

(con't)

Table 3.6. (con't)

Season	Wet	Early dry		Late dry	
Management system	Kraaled	Kraaled	Free-range	Kraaled	Free-range
Experimentally determined weight gains (kg/day)	0.7[1]	-0.4[1]	-0.0[3]	-0.5[1]	
	0.5[1]	0.0[3]	-0.1[3]	-0.4[1]	
	0.5[2]				
	0.5[3]				
	0.3[3]				

Source: 1. Mittendorf (1963) cited by Oyenuga (1966); 2. Rose Innes (1966); 3. Leeuw (1971) cited by Crowder and Chheda (1977).

Energy is retained that is reflected in daily liveweight gains. The daily liveweight gain of 0.7 kg is slightly higher than the average values reported for grazing cattle in the region but lower than the highest values recorded for cattle on improved pastures (Oyenuga,1975). Under field conditions one would have to take account of disease status and the incidence of parasites like ticks which have been shown to affect animal performance (Frisch, 1976). The decreased intake of ME in the dry season is associated with daily losses in liveweight and this is more so in the late dry season and with kraaling management than in the early dry season. With kraaling , cattle lose 0.3 kg per day in the early dry season and 0.6 kg per day during the late dry season (Table 3.6). These values are within the range (0.0 to -0.5) reported for cattle weight losses during the dry season (Mittendorf, 1963 as cited by Oyenuga, 1966; Leeuw, 1971 as cited by Crowder & Chheda, 1977). On an annual basis the calculated liveweight gains and losses would result in a net gain of 41 kg for the kraaled cow and 79 kg for the free-ranging cow.

When the individual activities are examined, one finds that under both kraaled and free-range conditions the proportion of daily ME intake that is utilized for standing or ruminating is 3% during the wet season and approximately 4% during both the early dry and late dry seasons (Table 3.6). Walking in all its forms accounts for 7% of ME intake during the wet season, 19 and 12% for kraaled and free-range

situations during the early dry season, and 29 and 24% during the late dry season, respectively. Forced walking accounts for 20% of the ME intake during the late dry season under kraaling management but this is still less than the 24% observed for the free-ranging cow. The contribution of grazing costs to the cow's daily energy budget is less extreme. During the wet season 10% of ME intake is used during grazing and this increased slightly to 12% and 11% in the early and late dry seasons for kraaled cattle. The early and late dry season values for free-range cattle are 16 and 18%. The present analysis tends to indicate that the extent of activity *per se* is not the overriding factor that results in free-range cattle gaining twice the liveweight put on by cattle per annum under kraaling management but the fact that kraaling seriously prevented animals from ingesting much needed energy and other nutrients.

3.0.3 CASE B: TAMALE DISTRICT

3.0.3.1 Introduction

Tamale is located in the central part of the Guinea Savanna woodland region of Ghana (Figure 2), latitude 09° 25′ N and longitude 00° 53′ W. The landscape is flat and low-lying, being only about 180 m above mean sea level (Ghana Meteorological Services, 1972). The district of Tamale covers about 1800 km^2 and in 1978 it carried 68,074 head of cattle (Veterinary Services, Tamale, 1978). The composition of cattle herds was 85% West African Shorthorn, 12% Sanga and 3% N′Dama. Cows and heifers made up 63% of herd total.

Management of cattle is similar to that of the Bawku District except that year-round kraaling is the rule and free-ranging is the exception. Cows are milked in the morning and driven off to graze communal grazing grounds until sunset when they are returned to the kraal.

3.0.3.2 Climatic Environment

Figure 3 illustrates the monthly variation in temperature, in relation to the Bawku and Techiman districts. Overall, the climate of Tamale is very similar to that of Bawku. The mean annual temperature for Tamale is 27.8°C and mean maximum and minimum temperatures are 33.5 and 22.2°C, respectively. However, during February and March, maximum temperatures exceed 37°C (Table 3.7). This

Table 3.7. Climatic data of the Tamale District.

Month	Air temperature (°C)			Humidity[2] (%)		Raindays[2] (days)	Rainfall[2] (mm)
	Max.[1]	Min.[1]	Mean[2]	09h00	15h00		
Jan.	35.6	19.9	27.6	35	18	1[3]	3
Feb.	37.4	23.1	30.1	44	22	1	9
Mar.	37.2	24.6	30.9	58	30	4	53
Apr.	34.9	24.3	30.0	69	44	7	85
May	33.5	23.5	28.5	75	54	8	117
Jun.	31.1	22.4	26.9	81	63	11	143
Jul.	30.2	22.2	26.1	84	66	12	147
Aug.	29.5	22.0	25.8	85	69	14	197
Sep.	30.0	21.8	25.9	86	69	18	226
Oct.	32.4	22.0	27.3	78	57	10	89
Nov.	34.6	21.0	27.8	62	38	2	14
Dec.	35.0	20.1	27.4	65	25	1	3
Mean	35.5	22.2	27.8	68	46		
Total						90	1 084

[1]Temperatures are derived from climatological tables (1962 to1972, excluding 1970), Ghana Meteorological Services, 1972.

[2]20 to 60 year data from the Agricultural Extension Handbook (1977), Ghana.

[3]Days with 0.25 mm or more of rainfall.

could have unfavourable effects on grazing cattle because the customary nightly kraaling practice permits grazing only during the day. The low temperatures in January and December occur during the night and are associated with the occurrence of the harmattan.

Relative humidities are low during the harmattan season (December to February) and water resources are scarce. Relative humidity at 09h00m is at a low value of 35% in January, gradually increasing to about 70% at the start of the wet season (April), attaining a peak (86%) in September and trailing off to a little over 60% by the end of the year (Table 3.7). Relative humidity values at 15h00m are significantly lower than at 09h00m but the seasonal trend is still identical. The probability of rain falling on any particular day is much higher during May to October when relative humidity at 15h00m is over 50%. At the beginning and end of the calender year the number of days that receive 0.25 mm or more of rainfall per day (raindays) are less than 5 per month. During the wet season one out of every two or three days receives 0.25 mm or more of rainfall. September has 18 raindays and an average rainfall of 226 mm. The amount of rainfall tapers off in both directions after the peak in September. On the average 90 days in the year receive 0.25 mm or more of rainfall per day giving a rainfall total of 1084 mm.

Despite the apparently high amounts of precipitation, wide seasonal and annual variations occur so that the annual

dependable rainfall, that is the least amount that would fall, is estimated as 864 mm (Benneh, 1971). Furthermore, evapotranspiration rates are high and with an estimated water storage capacity of the sandy soils of the district as 305 mm, the district actually has an annual rainfall deficit of 711 mm and this occurs mainly in the dry season (Benneh, 1971). Solar radiation levels have been estimated as 1.9 kJ per cm^2 (Ussher, 1969). There are 7.0 h/day and 8.6 h/day of bright sunshine during the wet and dry seasons, respectively. The daily photoperiod is approximately 12 h throughout the year (Walker, 1962).

3.0.3.3 Non-climatic and Other Background Information

The Guinea savanna zone is sparsely populated in Ghana and population densities outside of urban centers are 4 to 10 persons per km^2 (Benneh, 1971). People in the Tamale district are mostly farmers who cultivate consumable and cash crops as well as raise cattle. Land rotation is practised in all areas but rotations are generally shorter near settlements. The land tenure system is communal. Fallow fields (as well as the uncultivated woodland savanna) provide grazing for animals. Grass genera include tall tussock species such as *Andropogon*, *Hypparhenia* and *Pennisetum*. Others include *Aristida* spp. *Milinis* spp., *Loudesia* spp. and *Sporobolus* spp. Soils have low inherent fertility and the dung obtained from kraaled cattle is used to fertilize farms near the settlements. After the crops

have been harvested, cattle are allowed to forage the standing residues. Animals also have access to by-products of the harvested crops which include Bulrush millet (*Pennisetum typhoides*, Stapf. and Hubbert), Guineacorn (*Sorghum vulgare*), Groundnuts (*Arachis hypogaea*, Linn.) and Rice (*Oryza sativa*). Most of these crops are harvested between October and December. Crop residues are therefore, available in greater quantities to cattle during the early dry season (November to January) than during the late dry season (February to early April).

Burning of vegetation is an integral part of the land clearing process in the Tamale district. People also set the vegetation afire for hunting purposes. The burning of vegetation during the early part of the dry season is believed to enhance the growth of tall grasses (Ramsay and Rose-Innes, 1963). Controlled burning can be a good management tool in providing fresh nutritious herbage to foraging cattle. However, the peasant herdsman has not the means of controlling fire once it is started and the result is that large areas of the savanna woodland become bare and it then becomes necessary to drive cattle to far away places to graze and water.

Tsetse flies (*Glossina* species) abound in all parts of the Guinea savanna zone. The exception is specific areas which have been made tsetse-free by a combination of spray techniques and vegetation clearance. Dense woodland usually along rivers and streams are very suitable habitats of

various species of tsetse fly.

3.0.3.4 Estimates of Feed Quality, Diet Composition and Intake

Table 3.8 summarizes by season and fodder group, the quality of feed consumed by cattle in the Tamale District. Listed in Table 3.8 also are the principal fodder species encounted by grazing animals and the per cent availability of fodder species to the animal. The principal grazed grass genera are *Andropogon*, *Hyparrhenia*, *Schizachyrium* and *Loudesia* (Rose-Innes, 1962; F.A.O., 1968; Wills, 1962). Grazed leguminous trees and shrubs include *Acacia albida*, and species of *Afzelia*, *Bauhinia* and *Pterocarpus*. The forbs, *Borreria stachydea* and *Jacquemontia tamnifolia* are also considered to be important dry season fodder plants for cattle (Boudet, 1970). Also crop residues such as bulrush millet, sorghum, groundnuts and rice are available to grazing cattle during the dry season.

There is a wide range of DM contents of all fodders during the different seasons. In general, DM values are low during the wet season and substantially high during the late dry season (Table 3.8). The DM content of grasses varies from 27 to 70%; of legumes 35 to 37%; forbs 25 to 28%; and crop residues 45 to 60%. Concomitant with these changes in DM, the CF content of grasses falls from 27 to 40%; of legumes from 17 to 28%; forbs 20 to 35%; and crop residues 20 to 40%. Crude protein values are, except for the legumes,

Table 3.8. Principal fodders and estimates of feed composition (weighted averages of available fodders) available to cattle in the Tamale District - Wet season.

	Grasses	Legumes	Forbs
Principal fodders	*Andropogon gayanus vars**** *Hyparrhenia subplumosa*** *Andropogon pseudapricus** *Schizachyrium spp.*° *Loudesia acuminata*°	*Acacia albida*° *Afzelia africana*° *Bauhinia rufescens*° *Pterocarpus erinaceus*°	*Borreria stachydea*° *Jacquemontia tamnifolia*°
Composition			
Dry matter, (%)	27 (20-45)	35 (30-45)	25 (20-30)
Crude fiber, (%)	30 (27-40)	24 (18-28)	22 (20-30)
Crude protein, (%)	8 (5-10)	14 (11-18)	10 (8-12)

Percent of species available to animal: *** >50%; ** 30-50%; * 5-30%; ° <5%

Table 3.8. (continued) Early dry season.

	Grasses	Legumes	Forbs	Crop residues
Principal fodders	*Andropogon gayanus vars.*** *Hyparrhenia subplumosa*** *Pennisetum pedicallatum** *Andropogon pseudapricus** *Heteropogon contortus**	*Acacia albida*° *Afzelia africana*° *Bauhinia rufescens*° *Pterocarpus erinaceus*°	*Borreria stachydea*° *Jacquemontia tamnifolia*°	*Spiked millet*° *Sorghum*° *Groundnut haulms* *Rice straw*
Composition				
Dry matter (%)	45 (35-60)	37 (35-42)	30 (25-35)	45 (20-85)
Crude fiber (%)	33 (30-40)	20 (17-25)	28 (20-35)	30 (20-40)
Crude protein (%)	5 (3-6)	14 (13-18)	5 (3-7)	6 (3-14)

Percent of species available to animal: *** >50%; ** 30-50%; * 5-30%; ° <5%

Table 3.8. (continued) Late dry season.

	Grasses	Legumes	Forbs	Crop residues
Principal fodders	*Andropogon gayanus vars.**** *Hyparrhenia spp.*** *Pennisetum pedicillatum** *Andropogon pseudapricus*** *Aristida hordeacea*°	*Acacia albida*° *Afzelia africana*° *Bauhinia rufescens*° *Peterocarpus erinaceus*°	*Borreria stachydea*° *Jacquemontia tamnifolia*°	*Spiked millet*° *Sorghum*° *Groundnut haulms* *Rice straw*
Composition				
Dry matter (%)	70 (25-90)	35 (30-43)	30 (20-45)	60 (25-95)
Crude fiber (%)	33 (30-38)	24 (19-25)	25 (20-30)	30 (25-40)
Crude protein (%)	4.5 (2-7)	14 (11-18)	6 (5-10)	5.5 (2-10)

Percent of species available to animal: *** >50%; ** 30-50%; * 5-30%; ° <5%

very low. The CP content of grasses are from 2 to 10%; of legumes 11 to 18%; forbs 3 to 12%; and crop residues 2 to 14%. Estimated average values of DM, CF, and CP of the fodder species consumed by cattle are also included in Table 3.8. For example, the DM of grasses consumed during the wet season is 27%, CF is 30% and CP is 8%. Corresponding values during the early dry season are 45%, 33% and 5% and during the late dry season, the DM, CF and CP values are 70%, 33% and 4.5%, respectively.

Cattle consume different proportions of grass, legumes, forbs and crop residues during the different seasons. Estimates of the different proportions of the four fodder groups shown in Table 3.8 have been used to formulate a composite diet for grazing cattle during the wet and dry seasons.

Table 3.9 gives the estimated diet composition and also the daily intake of dry matter, energy and digestible protein by a 200 kg, non-pregnant West African Shorthorn heifer. Whereas there is a 2 to 4% increase in CF content of herbage consumed in the dry season over the wet season value of 30%, the CP values of 5.3 and 5.1% of early and late dry season herbage are all lower than the critical value of 6% required to maintain the bodyweight of Fulani cattle (Miller et al., 1963). The ME content of dry season herbage is about 10% lower than that of the wet season. The ME value of 7.9 MJ/kg DM of wet season herbage is comparable to that observed for many tropical grass species (Johnson et

Table 3.9. Estimated diet composition (weighted for proportions of principal fodders) and daily feed and nutrient intake in the Tamale District.

Season	Wet	Early dry	Late dry
Management system	Kraaled	Kraaled	Kraaled
Feed composition			
Crude fiber (%)	29.7	33.3	31.9
Crude protein (%)	8.2	5.3	5.1
Digestible energy (MJ/kg)	9.6	8.7	8.3
Metabolisable energy (MJ/kg)	7.8	7.2	6.8
Daily feed intake			
Dry matter (kg)	5.5	4.4	4.0
Digestible energy (MJ)	52.9	38.7	33.4
Metabolisable energy (MJ)	43.4	31.7	27.4
Crude protein (g)	451	233	204
Digestible crude protein (g) (a)[1]	211	52	40
(b)[1]	250	88	73

[1]Estimated intake based on (a) McDonald et al. (1973), and (b) NRC (1976).

al.,1967; Gohl, 1975). Daily dry matter intake for the different seasons were 5.5 kg, 4.4 kg and 4.0 kg or 2.75%, 2.2% and 2.0% of liveweight equivalent during the wet, early dry and late dry seasons, respectively. Consequently, daily intake of ME (MJ/day) was 43.4, 31.7 and 27.4 mJ during the wet season, early dry and late dry seasons. The low intake of poor quality DM in the dry season also results in low intakes of both CP and DCP. Estimates based on NRC (1976) indicate that the DCP intake of 250 g/day during the wet season is adequate to support a little less than 0.6 kg/day liveweight gain. The intake of 88 and 73 g/day of DCP during the early and late dry seasons are only 74% and 64%, respectively, of the A.R.C. (1965) minimum requirements for maintenance. Thus, protein intake is not only inadequate for minimal gain but also inadequate in meeting maintenance needs.

3.0.3.5 Estimates of Daily Amounts of Animal Activities

Cattle in the Tamale District are predominantly night kraaled during all seasons of the year and have only an average 10 h per day during which grazing and associated activities may be done. Within the constraints of this management system and the availability of herbage , daily amounts of animal activity have been compiled. The results are summarized in Table 3.10.

Forced walking doubles from 3 km in the wet season to

Table 3.10. Amounts of daily activities of cattle in the Tamale District.

Season	Wet	Early dry	Late dry
Management system	Kraaled	Kraaled	Kraaled
Activity per day			
Standing (h)	17	18	19
Walking (km)			
Forced walking[1]	3	6	12
Voluntary walking[2]	4	7	7
Grazing (h)	7	6	6
Ruminating (h)	6	6.5	7

[1]Average walking speed approximately 4 km/h.

[2]Average walking speed of between 0.3 and 0.6 km/h.

6 km in the early dry season and again to 12 km in the late dry season. Voluntary walking increases from 4 km in the wet season to 7 km in the early and late dry seasons. The hours spent standing are between 17 and 19 h in all seasons and grazing time during both the early and late dry seasons is 6 h, one hour lower than the wet season. The reduction in effective grazing time during the dry season is related to the constraints placed on cattle by the limited time available for grazing activity, the scarcity of feed and prevailing hot conditions. Ruminating time increased by half-hourly margins from 6 h during the wet season to 7 h during the late dry season. The above estimates of the amounts of daily activities could vary depending on the settlemnt type and the degree of utilization for crop production of the land nearest the settlement. The amount of walking would be less for cattle in rural villages with a nearby source of water supply and large uncultivated tree savanna than for communities which lack these facilities.

3.0.3.6 Daily Energy Budget for a 3-year-old, Non-pregnant West African Shorthorn Heifer

Table 3.11 summarizes the components of the estimated daily energy budget for a 3-year-old, non-pregnant West African Shorthorn heifer. Metabolizable energy intake (MJ/day) during the wet, early dry and late dry seasons were, respectively, 43.4, 31.7 and 27.4. These values are directly related to feed intake and the lower digestibility

Table 3.11. Daily energy budget for a 3-year-old non-pregnant West African Shorthorn heifer in the Tamale District.

Season	Wet	Early dry	Late dry
Management system	Kraaled	Kraaled	Kraaled
Weight of animal (kg)	200	200	200
Daily intake			
Dry matter (kg)	5.5	4.4	4.0
Metabolisable energy (MJ)	43.4	31.7	27.4
Daily output			
(a) Maintenance (MJ)	24.9	24.9	24.9
(b) Activity (MJ)	9.2	11.3	14.0
Standing	1.1	1.2	1.2
Forced walking	1.3	2.5	5.0
Voluntary walking	1.7	2.9	2.9
Grazing	3.9	3.4	3.4
Ruminating	1.2	1.3	1.4
Total (a+b) (MJ)	34.1	36.2	38.9
Estimated daily balance			
Energy balance (MJ)	+9.3	-4.5	-11.5
Weight gain (kg)	+0.5	-0.2	-0.6
Experimentally determined weight gains (kg/day)	0.7[1]	-0.4[1]	-0.5[1]
	0.5[1]	0.0[3]	-0.4[1]
	0.5[2]	0.0[3]	
	0.5[3]	-0.1[3]	
	0.3[3]		

Source: 1. Mittendorf (1963) cited by Oyenuga (1966); 2. Rose Innes (1966); 3. Leeuw (1971) cited by Crowder and Chheda (1977).

of DM of dry season feeds. Utilization of daily ME intake was largely for maintenance, and this represented 57, 79 and 91% of total ME intake during the respective seasons. Since cattle have to engage in one kind of activity or the other in securing and metabolizing the feed, energy utilization for such activities were 21% of total daily ME intake during the wet season, and 36 and 51% during the early and late dry seasons, respectively. Hence, whereas the sum of the daily maintenance expenditure and total activities was only 79% of daily ME intake during the wet season, this increased to 114% during the early dry season and to 142% during the late dry season (Table 3.11). The estimated values were 34.1, 36.2 and 38.9 MJ per day for the wet season, early dry season and late dry season, respectively. Cattle gained in liveweight during the wet season when adequate amounts of forage were consumed but lost weight during the early and late dry seasons when feed intake was insufficient to maintain liveweight.

Assuming that the energy content of both liveweight gain and loss is 20 MJ/kg (A.R.C., 1965; M.A.F.F., 1975; Webster, 1979), the analysis of the daily energy budget for a typical West African Shorthorn heifer indicates that the animal gains about 0.5 kg of liveweight per day from mid-April to the end of October (93 kg total gain). Between November and January she loses approximately 0.2 kg per day (or a total of 21 kg) and again loses about 0.6 kg/day between February and the first two weeks of April (or 44 kg)

(Table 3.11). On an annual basis, such an animal will gain 28 kg or 14% of its initial liveweight.

The daily liveweight gain of 0.5 kg is slightly less than the average of the values of 0.5 and 0.7 kg/day estimated from liveweight gains in the rainy seasons reported by Mittendorf (1963), (as cited by Oyenuga, 1966). The gains are however, comparable to 0.45 kg/day reported by Rose-Innes (1966) and 0.49 kg/day reported by Leeuw 1971 (cited by Crowder and Chheda, 1977). During the early part of the dry season a typical animal under the kraaling management system loses 0.2 kg liveweight per day. During the late dry season daily liveweight loss is 0.6 kg/day (Table 3.11). The losses during the early dry season tend to be much higher than values obtained from grass/legume pastures during identical periods (Oyenuga, 1975) but the average of the early and late dry season liveweight losses is comparable to the value of 0.41 kg/day observed during the dry season by Mittendorf (1963) (cited by Oyenuga, 1966). The liveweight losses may be explained by the low intakes of ME and the greater extent of activities, particularly, walking and grazing during the dry season. During the wet season energy utilization for forced walking represented only 3% of daily total ME intake whilst voluntary walking accounted for 4%. In the early dry season, with feed resources becoming scarce, there was more than a two-fold increase in energy utilization for both forced walking (8%) and voluntary walking (9%). Forced walking

alone accounted for 18.4% of total daily ME intake during the late dry season. During this period the two components of walking represented a daily energy expenditure of 8 MJ or 29% of daily ME intake (Table 3.11).

Energy utilized for grazing activity during the dry season was 3.4 MJ/day or 86% of that of the wet season. Energy expenditure in standing and ruminating were similar during the different seasons and varied between 1.1 and 1.4 MJ per day.

3.0.4 CASE C; TECHIMAN DISTRICT

3.0.4.1 Introduction

Techiman is an agricultural-commercial town located within the forest-savanna transition zone (Derived savanna zone) of Ghana (Figure 3.2). Techiman's situation is latitude 07° 35′N and longitude 01° 55′W. Unlike the previous districts of Bawku and Tamale, the Techiman district is 'high country', lying about 430 m above mean sea level (Ghana Meteorological Services, 1972). Extensive cultivation and burning of vegetation has helped to maintain grassy fallows interspersed with trees of varying density. The predominant breed of cattle is the West African Shorthorn. On a regional basis the cattle population of the Brong Ahafo Region of Ghana (of which the Techiman district is part) is only about 6% of that of either the Northern or Upper Regions (represented by the Tamale and Bawku Districts, respectively). In 1976, the Brong Ahafo region had a cattle population of 17,489 (Ghana Veterinary Services, 1977). Cattle are managed largely by kraaling systems.

3.0.4.2 Climatic Environment

The general pattern of temperature, relative humidity, raindays and rainfall in the Techiman district is shown in Figure 3. Details of these climatic parameters are given in

Table 3.12. Climatic data of the Techiman District[1].

Month	Air temperature (°C)			Humidity (%)		Raindays[2] (days)	Rainfall (mm)
	Max.	Min.	Mean	09h00	15h00		
Jan.	32.2	19.2	25.7	72	34	1	8
Feb.	33.9	21.4	27.9	75	38	4	40
Mar.	33.1	21.8	27.5	81	50	8	93
Apr.	32.2	21.7	27.0	82	59	9	149
May	31.0	21.5	26.3	86	65	12	182
Jun.	29.2	20.8	25.0	88	71	14	201
Jul.	28.1	20.7	24.4	89	71	9	93
Aug.	27.5	20.6	24.0	90	73	8	72
Sep.	28.3	20.6	24.5	90	73	13	198
Oct.	29.4	20.5	25.0	89	71	15	217
Nov.	30.6	20.6	25.6	87	62	4	72
Dec.	30.4	19.9	25.2	84	53	3	20
Mean	30.5	20.8	25.7	84	60		
Total						100	1 345

[1]Data derived from climatological tables (1962 to 1972), Ghana Meteorological Services, 1972.

[2]Days with 0.25 mm or more of rainfall.

Table 3.12. The monthly mean temperatures are lower than those in the Bawku and Tamale districts. The annual mean temperature of 25.7°C is 2°C lower than that of the Tamale district. There are not many months with maximum temperatures in excess of 32°C and the highest maximum temperature of 34°C recorded in February is 6°C lower than the maximum temperatures in the Bawku district. Relative humidity is very high throughout the year and increases steadily from January to reach a peak of 90% in August/September. Thereafter relative humidity declines but stays above 50% except for January and February at 15h00m. Rainfall occurs in two regimes; a major one occurring between March and July with a break in August then followed by a minor one in September to early November. December to February are regarded as dry months and have four or less days in a month with 0.25 mm or more of rainfall per day. On an annual basis 100 days per year are raindays and during June, September and October approximately one out of every two days is a rainday (Table 3.12). Total annual rainfall is 1345 mm of which 990 mm is considered dependable (Ussher, 1969). If there is any rainfall deficiency at all, it is very likely to be minimal. Mean daily solar radiation is 1.7 kJ per cm^2 and the number of bright sunshine hours per day are on the average 5 h and 7 h for the wet and dry seasons, respectively (Ussher, 1969).

3.0.4.3 Non-climatic and Other Background Information

The Techiman District is within the farming zone where tree crops such as *cacao* and palm form an important component of the farming system. The symbol of the office of chieftaincy is the stool. The land is vested in the stool and land tenancy is a common practice. Grazing is done on stool lands in an identical way as is done on communal lands of the Tamale and Bawku districts. Cattle are kraaled in the evenings and during the day they are driven across fallow fields by hired herdsmen or adult members of the family. The characteristics of the predominant breed (West African Shorthorn) have been given in Table 3.1.

The tsetse fly incidence in this district is more severe than in the Tamale and Bawku districts and may result in animals being subjected to the effects of transient trypanosomiasis.

3.0.4.4 Estimates of Feed Quality, Diet Composition and Intake

Many of the grasses present in the Guinea savanna zone are also prevalent in the derived savannas. They include the genera *Andropogon*, *Hyparrhenia* and *Pennisetum*. Also found on cleared lands and along road sides are the species *Panicum maximum* and *Loudesia arundinacea*. Leguminous fodder plants may be represented by the introduced species, *Centrosema pubescens*, *Desmodium intortum* and *Stylosanthes gracilis*.

Forbs occur within the grass/legume mixtures and among the cultivated crops for human consumption are maize (*Zea mays*), cassava (*Manihot esculentum*) and groundnuts (*Arachis hypogaea*). Residues from these crops may be available to cattle during the post-harvest season.

Table 3.13 summarizes the nutritive composition of the grasses, legumes, forbs and crop residues that comprise the diet of grazing cattle in the Techiman area. The data have been derived in a similar fashion as that described for the Bawku and Tamale districts. Dry matter contents of all fodder species increase from the wet season to the dry season, the increase being more marked for grasses and crop residues than for legumes. The DM content of forbs is low during the wet season and relatively high during the dry season but the dry season values are much lower than that of grasses and crop residues. The DM content of feed estimated to be consumed by cattle vary from 25 to 55% for grasses, 27 to 32% for legumes, 20 to 28% for forbs and 30 to 40% for crop residues (Table 3.13). The range of values actually encounted by the grazing animal is wider than these and is estimated between 15 and 85%. The CF and CP content of the different fodder species are also very variable (see values in parenthesis in Table 3.13) and herbage with high CP and low CF content is found to be more prevalent in the wet season than in the dry season. Legumes are high in CP content during all seasons.

Based on the above estimates of nutritive composition

Table 3.13. Principal fodders and estimates of feed composition (weighted averages of available fodders) available to cattle in the Techiman District - Primary wet season.

	Grasses	Legumes	Forbs
Principal fodders	*Panicum maximum**** *Andropogon tectorum*** *Pennisetum purpurceum*** *Hyparrhenia rufa** *Loudesia arundinacea*	*Centrosema pubescens*° *Desmodium spp.*°	*Forbs*
Composition			
Dry matter, (%)	25 (15-45)	27 (20-38)	20 (15-28)
Crude fiber, (%)	28 (20-35)	30 (25-35)	20 (18-30)
Crude protein, (%)	10 (8-15)	15 (10-20)	10 (8-13)

Percent of species available to animal: *** >50%; ** 30-50%; * 5-30%; ° <5%

Table 3.13. (continued) Mid-season.

	Grasses	Legumes	Forbs	Crop residues
Principal fodders	*Panicum maximum**** *Pennisetum purpureum*** *Hyparrhenia subplumosa*** *Andropogon tectorum** *Hyparrhenia rufa**	*Centrosema pubescens*° *Desmodium spp.*°	*Forbs*	*Maize stover*° *Cassava peelings*° *Groundnut haulms*°
Composition				
Dry matter (%)	30 (20-38)	30 (25-40)	28 (18-38)	30 (20-55)
Crude fiber (%)	30 (25-35)	37 (30-43)	26 (20-35)	22 (12-40)
Crude protein (%)	6 (4-10)	9 (7-12)	6 (5-8)	7 (5-12)

Percent of species available to animal: *** >50%; ** 30-50%; * 5-30%; ° <5%

Table 3.13. (continued) Secondary wet season.

	Grasses	Legumes	Forbs
Principal fodders	*Panicum maximum**** *Andropogon spp.*** *Pennisetum spp.*** *Hyparrhenia spp.** *Loudesia spp.*°	*Centrosema pubescens*° *Desmodium spp.*°	*Forbs* °
Composition			
Dry matter, (%)	25 (20-45)	28 (20-38)	20 (15-28)
Crude fiber, (%)	29 (20-40)	30 (25-40)	21 (18-30)
Crude protein, (%)	8.5 (6-14)	13 (10-17)	10 (8-13)

Percent of species available to animal: *** >50%; ** 30-50%; * 5-30%; °< 5%

Table 3.13. (continued) Dry season.

	Grasses	Legumes	Forbs	Crop residues
Principal fodders	*Andropogon tectorum**** *Panicum maximum*** *Hyparrhenia subplumosa*** *Loudetia arundinacea** *Imperata cylindrica*	*Centrosema pubescens*° *Desmodium spp.*°	*Forbs**	*Maize stover*° *Cassava peelings*° *Groundnut haulms*°
Composition				
Dry matter (%)	55 (20-85)	32 (25-48)	28 (20-40)	40 (28-85)
Crude fiber (%)	30 (27-38)	33 (28-38)	22 (18-30)	25 (20-40)
Crude protein (%)	6 (4-9)	8 (6-12)	7 (5-10)	6 (4-8)

Percent of species available to animal: *** >50%; ** 30-50%; * 5-30%; ° <5%

of the different fodders encounted by grazing cattle, an estimated composite diet with differing proportions of grass, legume, forbs and crop residues is presented in Table 3.14. In all seasons, CF varies from 27.8 to 31.0% and CP ranged from 6.0 to 9.0%. ME content of the diet varied from 7.9 MJ/kg for wet season feed to 6.9 MJ/kg for dry season feed. Intake of DM was 5.5 kg during the primary wet season, 4.5 kg during the mid-season or mini-dry season, 5.0 kg during the secondary wet season and 4.5 kg during the dry season. Consequently daily ME intake, MJ/day, during the respective seasons were 43.4, 32.4, 39.5 and 30.9. Because of the higher CP content of wet season feed compared to dry season feed, the intake of digestible crude protein (estimated from NRC, 1976) in g/day was 313, 130, 263 and 118 for the primary wet season, mid-season, secondary wet season and dry season, respectively. The estimates obtained by using the equation of McDonald et al. (1973) are much lower than these but they follow a similar trend. When the CP intakes are related to the minimum requirements for weight gain given by A.R.C. (1965) it is seen that DCP intake during the mid-season and dry season are just within the 120 g/day required for maintenance. The daily intake of 263 to 313 g/day during the wet season is apparently adequate to support a daily liveweight gain of 0.6 kg/day.

Table 3.14. Estimated diet composition (weighted for proportions of principal fodders) and daily feed and nutrient intake in the Techiman District.

Season	Wet (Primary)	Mid	Wet (Secondary)	Dry
Management system	Kraaled	Kraaled	Kraaled	Kraaled
Feed composition				
Crude fiber (%)	27.8	29.8	28.0	31.0
Crude Protein (%)	9.5	6.3	9.0	6.0
Digestible energy (MJ/kg)	9.6	8.7	9.6	8.3
Metabolisable energy (MJ/kg)	7.8	7.2	7.8	6.8
Daily feed intake				
Dry matter (kg)	5.5	4.5	5.0	4.5
Digestible energy (MJ)	52.9	39.5	48.1	37.7
Metabolisable energy (MJ)	43.4	32.4	39.5	30.9
Crude protein (g)	523	284	450	270
Digestible crude protein(g)(a)[1]	276	94	228	82
(b)[1]	313	130	263	118

[1]Estimated intake based on (a) McDonald et al. (1973), and (b) NRC (1976).

3.0.4.5 Estimates of Daily Amounts of Animal Activities

The daily amounts of animal activities are given in Table 3.15. Cattle have been estimated to spend 17 h standing during the primary and secondary wet seasons, 17.5 h during the mid-season and 18 h during the dry season. Forced walking increases minimally from 2 km during the wet season to 3 and 4 km during the mid-season and dry season, respectively. The distances walked during voluntary foraging activity are not great and they increase from 2 km during the wet season to 5 km during the dry season. The length of time spent grazing varied between 6.5 and 7 h. In the dry season cattle managed to increase their grazing time to 7 h and feed intake increased to the same level attained during the mid-season. The number of ruminating hours also increased from 6 h in the wet season to 7 h during the dry season, a reflection of the increase in CF values and general poor quality of the feed.

Table 3.15. Amounts of daily activities of cattle in the Techiman District.

Season	Primary wet	Mid-	Secondary wet	Dry
Management system	Kraaled	Kraaled	Kraaled	Kraaled
Activity per day				
Standing (h)	17	17.5	17	18
Walking (km)				
Forced walking[1]	2	3	2	4
Voluntary walking[2]	2	4	2	5
Grazing (h)	7	6.5	6.5	7
Ruminating (h)	6	7	6	7

[1]Average walking speed approximately 4 km/h.

[2]Average walking speed of between 0.3 and 0.6 km/h.

3.0.4.6 Daily Energy Budget for a 3-year-old, Non-pregnant West African Shorthorn Heifer

The daily energy budget of a 3-year-old, non-pregnant West African Shorthorn heifer is given in Table 3.16. The daily intake of ME (MJ/day) is estimated at 43.4 during the primary wet season and slightly lower (39.5 MJ) during the secondary wet season. During the mid-season or mini-dry season ME intake is 32.4 MJ/day and this decreases slightly to 30.9 MJ/day during the dry season. A 200 kg animal with maintenance energy expenditure of 24.9 MJ/day uses between 60 and 80% of its total daily ME intake for this basal activity during all seasons. On the average 7.7 MJ/day of ME is utilized for animal activities during the wet seasons but this increases to about 10 MJ/day during the dry season. When expressed on the basis of daily ME intake, daily activities represented 18, 28, 19 and 37% of daily ME intake during the primary wet season, mid-season, secondary wet season and dry season, respectively. The individual activities that contributed significantly to daily energy expenditure were grazing (9 to 13%) and combined forced and voluntary walking during the dry season (9 to 12%) (Table 3.16). Energy expenditure involved in standing and ruminating represented between 3 and 5% of total daily ME intake. When the energy utilised for maintenance and daily activities is subtracted from the daily ME intake there is a net gain during the wet seasons and a net loss during the

Table 3.16. Daily energy budget for a 3-year-old non-pregnant West African Shorthorn heifer in the Techiman District.

Season	Primary wet	Mid	Secondary wet	Dry
Management system	Kraaled	Kraaled	Kraaled	Kraaled
Weight of animal (kg)	200	200	200	200
Daily intake				
Dry matter (kg)	5.5	4.5	5.0	4.5
Metabolisable energy (MJ)	43.4	32.4	39.5	30.9
Daily output				
(a) Maintenance (MJ)	24.9	24.9	24.9	24.9
(b) Activity (MJ)	7.8	9.1	7.5	10.3
Standing	1.1	1.1	1.1	1.2
Forced walking	0.8	1.3	0.8	1.7
Voluntary walking	0.8	1.7	0.8	2.1
Grazing	3.9	3.6	3.6	3.9
Ruminating	1.2	1.4	1.2	1.4
Total (a+b) (MJ)	32.7	34.0	32.4	35.2
Estimated daily balance				
Energy balance (MJ)	+10.7	-1.6	7.1	-4.3
Weight gain or loss (kg)	+0.5	-0.1	+0.4	-0.2
Experimentally determined weight gains (kg/day)	0.7[1] 0.5[1] 0.5[2] 0.5[3] 0.3[3]			-0.5[1] -0.4[1]

Source: 1. Mittendorf (1963) cited by Oyenuga (1966); 2. Rose Innes (1966); 3. Leeuw (1971) cited by Crowder and Chheda (1977).

dry season. Conversion to liveweight gains or losses by the factor 20 MJ ME per kg of gain or loss (Webster, 1978; A.R.C., 1965) gives a daily weight gain of 0.5 kg during the primary wet season and 0.4 kg during the secondary wet season. Cattle lose 0.1 kg per day during the mid-season and 0.2 kg during the dry season. A summation of the seasonal liveweight changes results in annual liveweight gains of 73 kg. The daily weight gains of 0.4 to 0.5 kg are within the range 0.0 to 0.7 kg observed by other experimenters with grazing cattle (Oyennga 1966; Crowder and Chheda 1977; Antwi and Addei, 1977). Liveweight losses during the dry season are low compared to those obtained for cattle in the Tamale and Bawku districts. This may be explained by the fact that animals eat more during the dry season and expend less energy in daily activities in the Techiman district as compared to the previous districts. The overall annual weight gain of 73 kg is however, higher than the range of 45 to 68 kg found for grazing animals on savanna-type grazing lands (Smith 1965).

One may argue that the 73 kg gain in weight is a theoretical value which could be achieved under conditions of good animal health and the level of feed intake and degree of animal activities estimated for the Techiman district. The factors which operate against the achievement of this level of productivity in the Techiman district as well as in the previous case study districts of Tamale and Bawku will be treated more fully in the next section.

4. DISCUSSION

The predicted liveweight gains by 3-year-old female cattle from the case studies and experimental and field observations of liveweight gains by cattle in the three savanna study zones of West Africa are summarized in Table 4.1. The cattle in the various districts were predicted to gain between 28 and 79 kg per year. Rose Innes (1966) observed that cattle grazing coastal savanna (Guinea savanna zone) in Ghana gained 0.14 kg/day on a yearly basis while a similar level of performance was achieved in northern Nigeria (Sudan savanna zone) by cattle which grazed rangeland by day and stylo pasture by night (Leeuw, 1971 as cited by Crowder and Chheda, 1977). At the IEMUT Bouke station in the Ivory Coast (Derived savanna zone) N'dama bulls stocked at 0.5 head/ha annually gained 0.24 kg/day with daytime grazing of natural pastures oversown with stylo (Letenneur, 1971 as cited by Crowder and Chheda, 1977). The annual liveweight gain was therefore about 90 kg which is slightly more than the liveweight gain predicted for female cattle in the Techiman district of Ghana (Table 4.1).

Several reasons may be advanced for the differences between actual and predicted liveweight gain values. Some of these differences may be related to the limitations of the energy budget methodology. The accuracy with which estimates of animal energy budgets may be made depends on the reliability and completeness of the data used. Assumptions were made about the levels of feed intake and the energy

Table 4.1 Predicted liveweight gains by 3 year old female cattle and actual liveweight gains by cattle grazing savanna grassland in West Africa

District	Bawku (Sudan savanna)		Tamale (Guinea savanna)	Techiman (Derived savanna)
Management system	Free-range	Kraaled	Kraaled	Kraaled
Predicted liveweight gains				
annual (kg)	79	41	28	73
(kg/day)	+0.22	+0.11	+0.08	+0.20
wet season (kg/day)	+0.7	+0.7	+0.5	+0.4 to +0.5
dry season (kg/day)	-0.1 to -0.5	-0.3 to -0.6	-0.2 to -0.6	-0.1 to -0.2
Actual liveweight gains				
annual (kg)	51[1]	?	50[2]	90[3]
(kg/day)	+0.14[1]	?	+0.14[2]	+0.24[3]
wet season (kg/day)	?	?	+0.4[2]	?
dry season (kg/day)	?	?	?	?

Source: 1 Leeuw de, (1971) as cited by Crowder and Chheda (1977);
2 Rose Innes (1966);
3 Letenneur (1971) as cited by Crowder and Chheda (1977);
? No data available

values of feeds and of liveweight gains and losses. Disease and cattle breed factors were not taken into account in the calculations. The direct climatic (heat) effect on the cattle was not incorporated in the present calculations. Furthermore, because of lack of specific data related to the case study zones some subjective estimates had to be made especially for the quality of feed consumed by cattle, the digestibility of the feeds and the type and amounts of daily activities of the animals.

The critical factor affecting animal performance in terms of liveweight gains was metabolizable energy (ME) intake. This is directly related to the voluntary feed intake and the metabolizability of the feed. Although it has been assumed in the present study that cattle consume between 2 and 3% of their body weight equivalent of dry matter, under practical conditions the voluntary feed intake may vary even more among breeds and from season to season under changing pasture conditions. Apart from the physical and chemical characteristics of the feed, the environmental constraints on the animal such as disease and hot temperatures can reduce appetite and consequently the amount of feed consumed and the level of productivity (Lytle and Messing, 1976). For example, in a study in Australia by Frisch (1976), the control of ectoparasites (ticks) resulted in increased liveweight gains and accounted for 40% of the difference in field liveweights between Hereford x Shorthorn and the more tick-resistant Brahman x Shorthorn cattle.

Increased weight gain of a lesser magnitude was estimated for anthelmintic treatment against gastro-intestinal parasites, control of "pink-eye" disease and amelioration of high ambient temperature and solar radiation (Frisch, 1976).

There is the possibility that among the cattle breeds in West Africa, unselected animals could have lower daily liveweight gains relative to the predicted rates of liveweight gain obtained in the estimated energy budgets. Warwick and Cobb (1976) have summarized evidence on genetic variability in the maintenance energy requirements of cattle and concluded that although the information was scanty and somewhat conflicting it nevertheless strongly suggested the existence of such variability. Thus, the basal metabolism of the West African Shorthorn, Sanga or White Fulani could be lower than that previously assumed. The majority of Zebu cattle, as well as cattle native to Africa, are considered to have lower maintenance energy requirements per unit of body mass (McDowell, 1972). This may be related to their generally smaller mature body mass. Genetic differences within breeds in carcass composition with regard to different proportions and rates of fat and protein deposition would also alter the energy value of unit gain or loss in liveweight. Furthermore, liveweight loss from undernourished animals is largely as fat and muscle with bone contributing an insignificant part (Robinson, 1948; Seebeck and Tulloh, 1968; Seebeck, 1973; Price, 1976). For the present a single energy value of 20 MJ/kg liveweight

gain or loss is used as there is no specific datum available to enable one to make more precise adjustments for liveweight changes.

Cattle will normally harvest forage of better nutritional value than that indicated from proximate analysis of mechanically cut samples (McKay and Frandsen, 1969). Cattle also increase the number of their grazing bites and the time spent grazing in order to compensate for the sparseness of fodder and where feed is difficult to harvest (Stobbs, 1974). Stobbs (1974) found that cows on pasture difficult to harvest, consistently graze more intensively at dawn. The management practices of peasant farmers, especially those involving kraaling, in the West African savanna zones prevents cattle from grazing during dawn hours and forces the animals to attempt to graze during parts of the day that are hot and with high solar radiation. The liveweight losses in cattle during the dry season appear to be inevitable under present management practices and contribute to the overall low productivity of grazing cattle in the region.

What steps can be initiated to improve the beef production systems that prevail in the savanna regions of West Africa? The problem of livestock production in developing countries is, according to Pawley (1970), *"the need and also the difficulty of transforming a traditional industry into a price-oriented market economy."* A primary factor in achieving any transformation is the need to

strengthen domestic marketing for both meat and milk which would then serve as incentives to the farmer to change management practices and increase production. For any change to be practical, effective and adopted by nomads and other cattle owners, the changes must make sense to the cattle owners (Riney, 1970). There is therefore the need to undertake meaningful surveys and analyses to understand the socio-economic factors operating within the cattle producing rural communities. The production of beef from traditional systems will probably continue to play a dominant role in the meat supply of West African countries for some time.

At the village level, one means of solution would be the provision of avenues whereby cattle owners will find it more expedient to sell off their excess stock and keep only reasonable numbers of animals for reproduction. The technical objectives of a much needed extension programme would be to encourage a build-up of productive breeding herds and at the same time upgrading these herds by selective breeding with suitable cattle breeds that possess faster growth rates. Since in many areas (the universities and research centers may be the exception) no breeding records are kept, successful change will require increased education and modification of traditions. The use of productive sires provided by, for example, the research institutions is one area where, with relatively little expense, rapid progress could be made. This may be done on an exchange basis where relatively unproductive bulls from a

traditional herd may be exchanged for the genetically superior sires.

Another development which could be interrelated with the above, is the use of commercial feedlots for growing and finishing of cattle. Although sugarcane is not presently cultivated in West African countries for cattle feed, a majority of these countries are well suited for such a venture. Latin American studies (Preston, 1974, 1976; Montpellier and Preston, 1976) have given indication of sugarcane utilization for intensive cattle feeding. Feedlot trials in Kenya (Creek et al., 1976) have also given very favourable results from the use of sugarcane as cattle feed. Daily liveweight gains of between 0.6 and 1.0 kg have been achieved using local cattle breeds and crosses with European breeds (Creek et al., 1976). Similarly the use of banana tops for intensive beef feeding also could have potential in the more humid areas which favour production of bananas. In the arid regions of West Africa it might however be appropriate to utilize crops like sorghum and cassava for intensive beef production. Pilot schemes designed to test the viability of such enterprises could be started relatively easily. However, if proven technically viable, problems likely to be encountered would be in terms of capital investment and operating costs for large commercial enterprises.

Even in a modified form, the above schemes could be effective in providing a year round feed supply for cattle

and still be acceptable to the traditional livestock farmer. Of significance to West African cattle production would be the decrease in the dry season liveweight losses and consequent increase in overall productivity of beef cattle in the savanna areas. Furthermore, because the low productivity of cattle in these savanna areas is closely tied with the socio-economic conditions that exist in rural communities, it is imperative that governments should make genuine efforts to improve the standard of living conditions of these people in order to facilitate adoption of better cattle management techniques.

BIBLIOGRAPHY

Agricultural Extension Handbook (Ghana). 1977. Publication of the Ghana/German Agricultural Development Project, Northern and Upper Regions, Ghana.

Agricultural Research Council. 1965. The nutrient requirements of farm livestock. No. 2. Ruminants. Her Majesty's Stationery Office. London.

Antwi, M.K. and Addei, A.K. 1977. Productivity and nutritive value of tropical pasture of *Andropogon gayanus* (Gamba grass) under zero grazing. 1976-1977 Annual Report, Animal Research Institute, CSIR, Achimota, Ghana.

Armsby, H.P., and Fries, J.A. 1915. Net Energy Values of Feeding Stuffs for Cattle. J. Agr. Res. 3: 435-491.

Arnold, G.W. 1960. The effect of the quantity and quality of pasture available to sheep on their grazing behaviour. Aust. J. Agric. Res. 11: 1034-1043.

Baile, C.A. and Forbes, J.M. 1974. Control of feed intake and regulation of energy balance in ruminants. Physiological Reviews 54(1): 160-214.

Benneh, G. 1971. Water requirements and limitations imposed on agricultural development in Northern Ghana. *In* Factors of Agricultural Growth in West Africa. Proceedings of an International Conference, I.M. Ofori (ed.), pp. 71.

Bianca, W. 1965. Cattle in a hot environment. J. Dairy Res. 32: 291-345.

Blaxter, K.L. 1967. The Energy Metabolism of Ruminants, 2nd ed. , Hutchinson Scientific and Technical, London.

Blaxter, K.L., and Wainman, F.W. 1962. Unpublished work cited by Agricultural Research Council. 1965. Nutrient Requirements of Farm Livestock No. 2 Ruminants. Her Majesty's Stationery Office. London. pp. 221.

Bogdan, A.V. 1976. Tropical Pasture and Fodder Plants. Longman Group Ltd., London.

Bond, J. and McDowell, R.E. 1972. Reproductive performance and physiological responses of beef females as affected by prolonged high environmental temperatures. J. Anim. Sci. 35(4): 820-829.

Boudet, G. 1970. Management of savannah woodland range in West Africa. Proc. 11th Inter. Grassld. Congr., Surfers Paradise, Queensland. Australia. pp 1-3.

Bourn, D. 1978. Cattle, rainfall and tsetse *Glossina spp.* in Africa. J. Arid. Environ. 1(1): 49-61.

Brammer, H. 1962. Soils. *In* Agriculture and Land Use in Ghana, J. Brian Wills (ed.), Oxford University Press, London.pp. 88.

Butterfield, R.M. 1966. The effects of nutritional stress and recovery on the body composition of cattle. Res. Vet. Sci. 7: 168-179.

Chippendale, G.M. 1964. Determination of plant species grazed by open range cattle in Central Australia. Proc. Aust. J. Anim. Prod., 5:256-257.

Clapperton, J.L. 1964. The energy metabolism of sheep walking on the level and on gradients. Brit. J. Nutr. 18: 47-54.

Creek, M.J., Squire, H.A. and Mulder, J. 1976. Fresh sugarcane as a substitute for maize silage in beef cattle rations. World Rev. Anim. Prod. 12(3): 35-42.

Crowder, L.V. and Chheda, H.R. 1977. Forage and fodder crops. *In* Food Crops of the Lowland Tropics, C.L.A. Leakey and J.B. Wills (ed.), Oxford University Press, London. pp. 127-159.

Dickinson, A.G. 1960. Some genetic implications of maternal effects - an hypothesis of mammalian growth. J. Agric. Sci., Camb. 54: 378-390.

Elliott, R.C. 1967. Voluntary intake of low protein diets by ruminants. I. Intake of food by cattle. J. agric. Sci., Camb. 69: 375-382.

Everitt, G.C. 1968. Pre-natal development of uniparous animals with particular reference to the influence of maternal nutrition in sheep. *In* Growth and Development of Mammals, G.A. Lodge and G.E. Lamming (ed.), Butterworths, London. pp. 131-157.

Everitt, G.C. 1972. Protein production from beef. Proc. N.Z. Soc. Anim. Prod. 32: 185-203.

F.A.O. 1968. Land and water survey in the upper and northern regions of Ghana. Final Report, Vol. 1 - General. Food and Agriculture Organization, Rome.

F.A.O. 1969. African trypanosomiasis: Report of a joint FAO/WHO Expert Committee. Food and Agriculture Organization, Rome.

F.A.O. 1977. FAO/WHO/OIE Animal Health Yearbook, 1976. Food and Agriculture Organization, Rome.

Finch, V.A. 1976. An assessment of the energy budget of Boran cattle. J. Thermal Biology 1: 143-148.

Forbes, E.B., Kriss, M. and Braman, W.W. 1927. The influence of position of cattle as to standing and lying on the rate of metabolism. J. Agr. Res. 35: 947-960.

Frisch, J.E. 1976. A model of reasons for breed differences in growth of cattle in the tropics. Proc. Aust. Soc. Anim. Prod., 11:85-88.

Fuquay, J.W., Brown, W.H. and Poe, W.E. 1976. Response of lactating dairy cows to summer modifications in freestall housing. Proc. 71st Ann. Mtg., Amer. Dairy Sci. Assoc., pp. 138 (Abstr.).

Ghana Meteorological Services. 1972. Annual summary of climatological observations in Ghana. Ghana Meteorological Services Department, Legon, Ghana.

Ghana Veterinary Services. 1977. Annual Livestock Census, 1976. Veterinary Services Department, Accra.

Gohl, B. 1975. Tropical Feeds: Feeds Information Summaries and Nutritive Values. FAO, Rome.

Graham, N. McC. 1964a. Maintenance requirements of sheep indoors and at pasture. Proc. Aust. Soc. Anim. Prod. 5:272.

Graham, N. McC. 1964b. Energy costs of feeding activities and energy expenditure of grazing sheep. Aust. J. Agric. Res. 15: 969-973.

Graham, N. McC. 1966. Predicting energy requirements of sheep. Proc. Aust. Soc. Anim. Prod., 7: 364

Hafez, E.S.E. 1965. Environment and reproduction in farm animals. World Rev. Anim. Prod. 1: 118-128.

Hall, W.C. and Brody, S. 1933. The energy increment of standing over lying and the energy cost of getting up and lying down. Univ. Mo. Agr. Exp. Sta. Res. Bull. 180. pp. 31.

Hammel, H.T. 1956. Infrared emissivities of some arctic fauna. J. of Mammalogy 37(3): 375-378.

Harvey, W.R. 1960. Least-square analysis of data with unequal subclass numbers. USDA ARS-20-8.

Holmes, C.W., McLean, H.A. and Lockyer, K.J. 1978. Changes in the rate of heat production of calves during grazing and eating. N.Z. J. Agric. Res. 21: 107.

Holmes, C.W., Stephens, D.B. and Toner, J.H. 1976. Heart rate as a possible indicator of the energy metabolism of calves kept out-of-doors. Livest. Prod. Sci. 3: 333.

Hutton, J.B. 1962. The maintenance requirements of New Zealand dairy cattle. Proc. N.Z. Soc. Anim. Prod. 22: 12-20.

Jeffrey, H.B. and Berg, R.T. 1971. Evaluation of milk variables as measures of milk effect on pre-weaning performance of beef cattle. Can. J. Anim. Sci. 51: 21-30.

Johnson, W.L., Ordoveza, A.L., Hardison, W.A. and Castillo, L.S. 1967. The nutritive value of *Panicum maximum* (Guinea grass). II. Digestibility by cattle and water buffaloes, related to season and herbage growth stage. J. agric. Sci., Camb. 69: 161-170.

Joubert, D.M. 1954. The influence of winter nutritional depressions on the growth, reproduction and production of cattle. J. agric. Sci., Camb. 44: 5-66.

Journet, M. and Remond, B. 1976. Physiological factors affecting the voluntary intake of feed by cows: A Review Livestock Prod. Sci. 3(2): 129-146.

Keay, R.W. 1959. Vegetation map of Africa south of the Tropic of Cancer. Oxford University Press, London.

Lambourne, L.J. and Reardon, T.F. 1963. Effect of environment on the maintenance requirements of Merino wethers. Aust. J. Agric. Res. 14: 272-292.

Lamond, D.R. 1970. The influence of undernutrition on reproduction in the cow. Anim. Breeding Abstr. 38: 359-372.

Lane, D.A. 1962. The forest vegetation. *In* Agriculture and Land Use in Ghana, J. Brian Wills (ed.), Oxford University Press, London. pp. 160.

Langlands, J.P., Corbett, J.L., McDonald, I. and Reid, G.W. 1963. Estimates of the energy required for maintenance by adult sheep. Anim. Prod. 5: 1-9.

Leeuw, P.N. de 1977. Fodder resources and livestock development in northeast Nigeria. Trop. Agric. (Abstr.): 14377.

Lewis, J.G. 1977. Game domestication for animal production in Kenya: activity patterns of eland, oryx, buffalo and

zebu cattle. J. agric. Sci., Camb. 89: 551-563.

Lofgreen, G.P., Meyer, J.H. and Hull, J.L. 1957. Behaviour patterns of sheep and cattle being fed pasture or silage. J. Anim. Sci. 16: 773-780.

Lytle, L.D. and Messing, R.B. 1976. Appetite in the regulation of food intake for energy (Animal and Man). Prog. Fd. Nutr. Sci. 2: 49-58.

MAFF. 1975. Ministry of Agriculture, Fisheries and Food: Energy allowances and feeding systems for ruminants. Tech. Bull. No. 33. Her Majesty's Stationery Office, London.

Marshall, B. and Bredon, R.M. 1967. The nutritive value of *Themeda triandra*. East African Agric. and Forestry J. 32: 375-379.

McDonald, I.W. 1968. The nutrition of grazing ruminants. Nutr. Abstr. and Rev. 38(2): 381-400.

McDonald, P., Edwards, R.A. and Greenhalgh, J.F.D. 1973. Animal Nutrition. 2nd Ed. Oliver & Boyd, Edinburgh, pp. 201-204.

McDowell, R.E. 1972. Improvement of livestock production in warm climates. W.H. Freeman and Company, San Francisco. pp. 151.

McKay, A.D. and Frandsen, P.E. 1969. Chemical and floristic components of the diet of zebu cattle (*Bos indicus*) in browse and grass range pastures in a simi-arid upland area of Kenya. I. Crude Protein. Trop. Agriculture, Trin. 46(4): 279-292.

McLean, J. 1962. Unpublished, cited by Agricultural Research Council. 1965. Nutrient Requirements of Farm Livestock No. 2 Ruminants. Her Majesty's Stationery Office. London. pp. 221.

McLean, J.A. 1972. On the calculation of heat production from open-circuit calorimetric measurements. Br. J. Nutr. 27: 597-600.

Miller, T.B., Rains, A.B. and Thorpe, R.J. 1963. The nutritive value and agronomic aspects of some fodders in Northern Nigeria. II. Silages. J. Br. Grassld. Soc. 18: 223-229.

Ministry of Agriculture (Ghana). 1975. Current Agricultural Statistics (1974). Ministry of Agriculture Planning Division, Accra.

Montpellier, F.A. and Preston, T.R. 1976. Effect on animal performance of giving sugarcane chopped finely by machine, coarsely with a machete or derinded. Trop. Anim. Prod. 1(1): 27.

Montsma, G. 1963. Preliminary report on the production characters of three types of cattle in Ghana. Neth. J. Agric. Sci. 11: 364-377.

Morgan, J.H.L. 1972. Effect of plane of nutrition on subsequent liveweight gain, carcass and muscle characteristics and eating quality of meat in cattle. J. agric. Sci., Camb. 78: 417-423.

Murray, M., Morrison, W.I., Murray, P.K., Clifford, D.J. and Trail, J.C.M. 1979. Trypanotolerance - a review. World Anim. Rev. 31: 2-12.

N.R.C. 1976. Nutrient Requirements of Beef Cattle (No. 4). 5th revised edition. National Academy of Sciences, Washington, D.C.

Olubajo, F.O. 1970. Use of chromic oxide in indoor digestion experiments with tropical grass-legume mixture using White Fulani steers. Nigerian agric. J. 7: 105-110.

Ormerod, W.E. 1976. Ecological effect of control of African trypanosomiasis: a connection between the West African cattle industry and Sahelian drought is possible. *Glossina* vectors, Science 191(4229): 815-821.

Osuji, P.O. 1974. The physiology of eating and the energy expenditure of the ruminant at pasture. J. Range Management 27 (6): 437-443.

Osuji, P.O., Gordon, J.G. and Webster, A.J.F. 1975. Energy exchanges associated with eating and rumination in sheep given grass diets of different physical forms. Brit. J. Nutr. 34: 59-71.

Oyenuga, V.A. 1966. The level of Nigerian livestock industry. World Rev. Anim. Prod. 2(1): 91-101.

Oyenuga, V.A. 1967. Agriculture in Nigeria, F.A.O., Rome, Chap. 9.

Oyenuga, V.A. 1975. Intensive animal production on a subsistence scale. *In* Proceedings of the III World Conference on Animal Production, R.L. Reid (ed.), Sydney University Press, pp. 393-400.

Pawley, W.H. 1970. The indicative world plan for agricultural development. World Rev. Anim. Prod., FAO Special Issue No. 26, pp. 18-21.

Poston, H.A., Ulberg, L.C. and Legates, J.E. 1962. Analysis of seasonal fluctuations of reproductive performance in dairy cows. J. Dairy Sci. 45: 1376-1379.

Preston, T.R. 1974. Sugarcane as the basis for intensive animal production in the tropics. *In* Animal Feeds of Tropical and Subtropical Origin. Conference Proceedings, Tropical Products Institute, London, pp. 69-83.

Preston, T.R. 1976. Prospects for the intensification of cattle production in developing countries. *In* Beef Cattle Production in Developing Countries, A.J. Smith (ed.), University of Edinburgh, pp. 242-257.

Price, M.A. 1976. Changes in body composition associated with weight loss in early- and later-maturing types of steers. Aust. J. Agric. Res. 27: 729-738.

Ramsay, J.M. and Rose Innes, R. 1963. Some quantitative observations on the effects of fire on the guinea savanna vegetation of Northern Ghana over a period of eleven years. Sols. Afr. 8: 41-85.

Rattray, J.M. 1960. The grass cover of Africa. Food and

Agriculture Organization of the United Nations,

Riney, T. 1970. Wildlife and nomadic stocks in semi-arid lands. World Rev. Anim. Prod., F.A.O. Special Issue No. 26 Rome, FAO Agricultural Studies, No. 49.

Robertshaw, D. and Finch, V. 1976. The effects of climate on the productivity of beef cattle. *In* Beef Cattle Production in Developing Countries, A.J. Smith (ed.), Edinburgh, pp. 281-293.

Robinson, P. 1948. The effect of supermaintenance and submaintenance diets on mature Border Leicester-Cheviot ewes. J. agric. Sci. 38: 345-353.

Rose Innes, R. 1960. Sugar in the sky or beef for the butcher. *In* The First Grassland Symposium, pp. 53-63, Ministry of Agric., Accra.

Rose Innes, R. 1962. Grassland, pastures and fodder production. *In* Agriculture and Land Use in Ghana, J.Brian Wills (ed.), Oxford University Press, London, pp. 416.

Rose Innes, R. 1963. The behaviour of free-grazing cattle in the West African humid tropics: studies on a herd of West African Shorthorns on the Accra plains, Ghana. 1. Rainy season. Emp. J. Exp. Agric. 31: 1-13.

Rose Innes, R. 1966. The concept of the "woody pasture" in low-altitude tropical tree savanna environments. Proc. 9th Inter. Grassld. Congr., Sao Paulo, Brazil, pp. 1419-1423.

Seath, D.M. and Miller, G.D. 1948. Effect of water sprinkling with and without air movement on cooling dairy cows. J. Dairy Sci. 31: 361-366.

Seebeck, R.M. 1973. The effect of body weight loss on the composition of Brahman cross and Africander cross steers. II Dissected components of the dressed carcass. J. agric. Sci. 80: 411-423.

Seebeck, R.M. and Tulloh, N.M. 1968. Developmental growth

and body weight loss of cattle. II. Dissected components of the commercially dressed and jointed carcass. Aust. J. Agric. Res. 19: 477-495.

Sen, K.M. and Mabey, G.L. 1966. The chemical composition of some indigenous grasses of central savanna of Ghana at different stages of growth. Proc. 9th Inter. Grassld. Congr., Sao Paulo, Brazil, pp.763-771.

Sewell, M.M.H. 1976. The role of management in the control of helminth diseases. *In* Beef Cattle Production in Developing Countries, A.J. Smith (ed.), pp. 138-149.

Smith, C.A. 1962. The utilization of *Hyparrhenia* veld for the nutrition of cattle in the dry season. J. agric. Sci., Camb. 58: 173-178.

Smith, C.A. 1965. The grazing habits of African-owned, East African zebu cattle in Zambia (Northern Rhodesia). J. agric. Sci., Camb. 64: 295-298.

Smith, C.A. 1970. The feeding value of tropical grass pastures evaluated by cattle weight gains. Proc. 11th Inter. Grassld. Congr., Surfers Paradise, Australia, pp. 839-841.

Squire, F.A. 1962. Tsetse files. *In* Agriculture and Land Use in Ghana, J. Brian Wills (ed.), Oxford University Press, London, pp. 441-444.

Steel, R.G.D. and Torrie, J.H. 1960. Principles and Procedures of Statistics. McGraw-Hill Book Company, Inc. New York.

Stobbs, T.H. 1974. Rate of biting by Jersey cows as influenced by the yield and maturity of pasture swards. Tropical Grasslands 8:81-86.

Thompson, B.W. 1965. The climates of Africa, Oxford University Press, Nairobi.

Thompson, G.E. 1973. Climatic physiology of cattle. J. Dairy Res. 40: 441-473.

Ussher, A.K.L. 1969. Climatic Maps of Ghana for Agriculture. Ghana Meteorological Services, Legon.

Ustjanzew, W. 1911. The energy cost of ingestion by sheep. Biochem Z. 37: 475.

Vercoe, J.E. 1973. The energy cost of standing and lying in adult cattle. Br. J. Nutr. 30: 207-210.

Vercoe, J.E. and Springell, P.H. 1969. Effect of subclinical helminthosis on nitrogen metabolism in beef cattle. J. agric. Sci., Camb. 73: 203-209.

Veterinary Services, Tamale. 1978. Livestock Census (1977-78) of the Tamale District. Veterinary Services Department, Tamale, Ghana.

Walker, J. 1967. Ghana Livestock Development Handbook. Published by USAID/Ministry of Agriculture, Ghana.

Wardrop, I.D. 1965. The effects of plane of nutrition in early post-natal life on the subsequent growth and development of cattle. Aust. J. Agric. Res. 17: 375-385.

Warwick, E.J. and Cobb, E.H. 1976. Genetic variation in nutrition of cattle for meat production. World Rev. Anim. Prod. 12(1): 75-81.

Webster, A.J.F. 1967. Continuous measurements of heart rate as an indicator of the energy expenditure of sheep. Br. J. Nutr. 21: 769.

Webster, A.J.F. 1972. Act of eating and its relation to the heat increment of feeding in ruminants. Proc. int. Symp. Envir. Physiol. pp. 42.

Webster, A.J.F. 1978. Prediction of the energy requirements for growth in beef cattle. World Rev. Nutr. Diet. 30: 189-226.

Webster, A.J.F. 1979. Energy metabolism and requirements. *In* Digestive Physiology and Nutrition of Ruminants, D.C. Church (ed.), 2nd Ed., O & B Books, Oregon, pp. 210-229.

Webster, A.J.F. and Hays, F.L. 1968. Effects of beta-adrenergic blockage on the heart rate and energy expenditure of sheep during feeding and during acute cold exposure. Can. J. Physiol. Pharmacol. 46: 577.

Whyte, R.O. 1974. Tropical Grazing Lands: communities and constituent species. Dr. W. Junk b.v. Publishers, The Hague.

Wills, J.B. 1962. The general pattern of land use. *In* Agriculture and Land Use in Ghana, J. Brian Wills (ed.), Oxford University Press, London, pp. 201.

Worstell, D.M. and Brody, S. 1953. Res. Bull. Mo. Agric. Exp. Sta., No. 515.

Yassen, A.M. 1977. Respiratory responses of N'Dama and Boran cattle to climatic conditions in Nigeria. World Rev. Anim. Prod. 13(2): 33-41.

Yeates, N.T.M. 1964. Starvation changes and subsequent recovery of adult beef muscle. J. agric. Sci., Camb. 62: 267-272.

Young, B.A. 1966. Energy expenditure and respiratory activity of sheep during feeding. Aust. J. Agric. Res. 17: 355.

Young, B.A., Kerrigan, B. and Christopherson, R.J. 1975. A versatile respiratory pattern analyzer for studies of energy metabolism of livestock. Can. J. Anim. Sci. 55:17-22.